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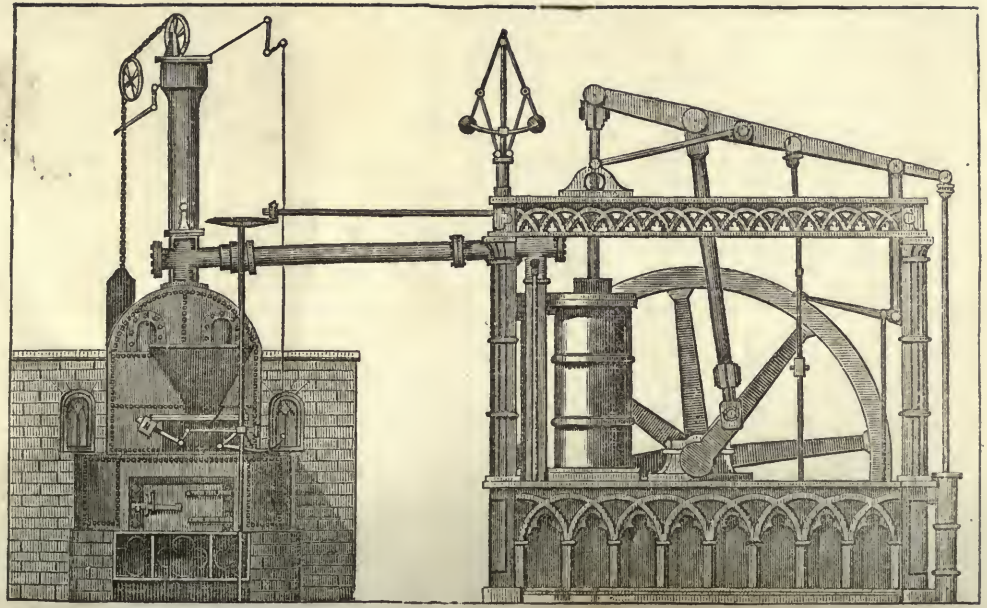

W BRUNTON'S PORTABLE ENGINE AND PATENT FIRE REGULATOR

THE

ARTIST'S GUIDE

AND

MECHANIC'S OWN BOOK,

EMBRACING

THE PORTION OF CHEMISTRY APPLICABLE

TO THE

MECHANIC ARTS,

WITH

ABSTRACTS OF ELECTRICITY, GALVANISM, MAGNETISM, PNEUMATICS, OPTICS, ASTRONOMY,

AND

MECHANICAL PHILOSOPHY.

ALSO

MECHANICAL EXERCISES

IN

IRON, STEEL, LEAD, ZINC, COPPER, AND TIN SOLDERING

AND

A VARIETY OF USEFUL RECEIPTS,

EXTENDING

TO EVERY PROFESSION AND OCCUPATION OF LIFE;

PARTICULARLY

DYEING, SILK, WOOLLEN, COTTON, AND LEATHER

BY JAMES PILKINGTON.

BOSTON:
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BY ALEXANDER V. BLAKE,

In the clerk's office of the district court of the southern district of New York.

PREFACE.

MECHANICS generally, having risen from families in the more humble stations of society, are not much favored with school education. Yet, in their case may be seen what is common in the allotments of Providence, that an evil is attended with a corresponding benefit. Thus, if poverty obliges many a youth to resort to the workshop for means of subsistence, instead of spending his time under tutors in obtaining from books the elementary instruction usually esteemed necessary to usefulness in life, it is a fact well known, that most mechanical pursuits are found favorable to mental developement. The fixtures of a mill, in multitudes of cases, seem to have answered about the same purpose in this respect, as the laboratory of the chemist, or the philosophical apparatus of the college professor. Instances have been frequent that the unlettered boy has risen, step by step, guided by his own energies, till he became distinguished for science and for inventions to bless the whole range of society. And it is believed, that no class in the community is more characterized than mechanics for the best of all possible endowments, the capability and habit of thinking for themselves.

The admission of this truth renders it desirable, that all possible facilities be placed within the reach of this most respectable and valuable portion of our community. Indeed, it is nearly as certain as mathematical demonstration, that if facilities are placed within their reach, the result will be auspicious. Such persons do not often neglect their opportunities for improvement. The young collegian may sometimes exhaust his paternal bounty, knowing or realizing but little of its value; but, the young mechanic looks upon his time and his means for improvement as better than money, inasmuch, as on them alone he depends for means of subsistence and the hope of future distinction.

The author of the following work has received his education in the manner described—not under academical supervision in classic halls; but amidst the ponderous wheels of powerful machinery, where he was his own teacher. And, many a time would it have saved him immense labor in his pursuits could he have had access to a few well made books elucidating the mysteries of his trade; it would have bouyed up his wearied spirit and led him on to renewed exertions in the attainment of knowledge. He has spent years in study which might have been saved for other objects. To furnish his brother mechanics with such a desideratum, the following pages have been prepared. If the work is not as good as it might be, he trusts it is as free from faults as the nature of the case can well admit. He has embraced a wide range, and was obliged, of course, to be concise. The mechanic has neither the ability to pro-

cure voluminous and elaborate treatises; nor, if procured, the leisure to study them.

From habits of intimacy with hundreds and perhaps with thousands of mechanics, he is well persuaded, that the present effort to promote their interests will be duly appreciated by them. And there is scarcely a laboring man in the community, whatever be his own particular trade, but what will find much in the Mechanic's Own Book suited to his own individual wants. An examination of it will convince any one of this fact.

Mechanics and artists have occasion to be proud of many names among their brethren. Roger Sherman, one of the most extraordinary men of Connecticut, in early life, was an humble shoe maker. The Rev. Thomas Baldwin, D. D., for many years, the venerable father as it were, of the Baptist denomination in this country, is said to have been a hard laboring blacksmith. One of the acting governors of the State of Massachusetts, now living in affluence and surrounded by men of eminence, when a boy was poor, and an apprentice in a printing office. Other cases of a similar sort might be named; and the story of Franklin is too familiar to my readers to need recital. The late Samuel Slater came to America with a few pounds only in his pockets; but he lived to see through his agency some of the most important relations and interests of society entirely changed; and died a man of great wealth. And who can tell all the important results now enjoyed by the world, that may be traced back to the untiring genius of Robert Fulton, once an itinerant painter? Or to the inde-

fatigable Oliver Evans, whose first studies were pursued after the hours of daily toil, in a wheelwright's shop by the light of his burning shavings. And Richard Arkwright, too, the founder of cotton spinning by machinery was bred to the trade of a barber, and has obtained one of the most endurable monuments to his genius the world ever raised. Indeed, it would fill a volume to give notes of all the mechanics that have acquired a praiseworthy fame.

In making the above allusions, it may not be inappropriate to mention the names of two other individuals who have obtained an enviable reputation. The first is Thomas Blanchard, extensively known in the United States for his mechanical skill, and now employed in the city of New York endeavoring to perfect a new invention. He will be remembered for ages to come for the benefits to society from his untiring genius. The second is E. Burritt, denominated, by governor Everett, the learned blacksmith, a resident of Worcester, Massachusetts. The appellation is a most just one. He is not thirty years of age, and labors eight hours daily, at his trade, yet he has learnt to read fifty different languages. Were the fact not supported by good authority, it would be incredible! Nor is Mr. Burritt satisfied with his present attainments; he continues to devote all his leisure time to study—that is, all not spent in manual labor and sleep. Apparently he has laid the foundation only of the superstructure to be erected thereon. What an example is his to the young mechanics of our country!

ARTIST'S GUIDE,

AND

MECHANICS' OWN BOOK.

CHEMISTRY.

OF CHEMICAL NOMENCLATURE.

From the revival of learning, after the fall of the Roman empire, to nearly the close of the seventeenth century, Chemistry was chiefly confined to those who followed it with alchemical views. Those persons, many of whom knew that they were deceiving their patrons, while others were desirous to conceal their self-delusion, or to create admiration by the appearance of having done much, were anxious to give every product of their laboratories a mysterious, extraordinary, or unintelligible name. As they did not act in concert, the same preparation obtained very different names; and, as they were, with few exceptions, as eminent for ignorance as effrontery, and carried on their operations at random, they examined but superficially the substances which they undertook to denominate, and knew not to what they were indebted for their leading properties. Such names as *horn moon, mercury of life, the wonderful salt, the salt with many virtues,* form but a small specimen of a prodigious number, equally inappropriate and ridiculous. Hence, when the dreams of alchemy were broken by the dawn of a more enlightened day—when men who had the promulgation of truth only for their object, became chemists, from a persuasion of the advantages which the

cultivation of that science would afford to mankind, they found it difficult to unravel the confusion which the misnomers of their predecessors had created. In proportion as discoveries were multiplied, the want of a regular and appropriate nomenclature increased, and formed a strong bar to the general diffusion of a taste for chemical researches. A few innovations, which were made by single individuals, in order to accommodate the language of chemistry to the improved state of knowledge, served only to show how much was still wanted. It is perfectly obvious that names founded upon a mistaken view of the properties of things, tend to the propagation of erroneous opinions, and that, when a vast number of substances are designated at random, without any connection in names, although nearly related in composition, the mere effort of memory to recollect these names, will exceed the effort which ought to be required for the acquisition of a science. Towards the close of the last century, therefore, several eminent French chemists determined to take a comprehensive view of the subject, and to remodel the whole system of chemical nomenclature—a task which they completed in 1797. Their object was to reject all the old names which were known to convey false ideas, but to preserve those which were not of this class, and to which custom had given a currency, scarcely and not usefully to be checked. They at the same time introduced new terms, of appropriate derivation; and the method of forming compound terms, so as to indicate the composition of compound bodies, was pointed out. This system of nomenclature possessed so much merit, that the adoption of it soon became general in France; and from thence, it spread with great rapidity to other countries, where it was received either entirely, or with such improvements as experience warranted. The objections which have been urged against it are futile; they have chiefly amounted to this,—that it is not absolutely perfect, and will, by the progress of discovery, hereafter require to be modified. On the contrary, a high eulogium on its value and opportune

establishment is conveyed by the opinion of several eminent chemists that the present state of chemistry could not be communicated, much less remembered, by the language previously in use.

The following table will exhibit the most important changes of terms which have been made, and more particular details will occur, as an account of each substance gives occasion:

Old names.	*New names*
Acetous Salts, - - -	Acetates.
Acid of vitriol, phlogisticated,	Sulphurous acid.
—— of alum - - -	Sulphuric acid.
—— of vitriol - - -	
—— vitriolic - - -	
—— of sulphur - -	
—— of nitre, phlogisticated,	Nitrous acid.
—— of nitre, dephlogisticated,	Nitric acid.
—— of saltpetre - -	
—— of sea-salt - -	Muriatic acid.
—— marine - - -	
—— dephlogisticated marine	Oxygenized muriatic acid.
—— ærial - - - -	Carbonic acid.
—— of chalk - - -	
—— cretaceous - -	
—— calcareous - -	
—— of charcoal - -	
—— mephitic - - -	
—— of spar or fluor	Fluoric acid.
—— sparry - - -	
—— of borax - - -	Boracic acid.
—— of arsenic - -	Arsenic acid.
—— of tungsten - -	Tungstic acid.
—— of wolfram - -	
—— of molybdina -	Molybdic acid.

Old names.	*New names.*
Acid of apples	Malic acid.
—— of sugar	Oxalic acid.
—— saccharine	
—— of wood sorrel	
—— of lemons	Citric acid.
—— of cream of tartar	Tartaric acid.
—— of benzoin	Benzoic acid.
—— of galls	Gallic acid.
—— of amber	Succinic acid.
—— of ants	Formic acid.
—— of cork	Suberic acid.
—— of phosphorus, phlogisticated	Phosphorus acid.
—— of phosphorus, dephlogisticated	Phosphoric acid.
—— of silk worms	Bombic acid.
—— of fat	Sebacic acid.
—— sedative	Boracic acid.
—— of lac	Laccic acid.
—— of milk	Lactic acid.
—— saccholactic	Mucous acid.
—— of sugar of milk	
Air,	Gas.*
— dephlogisticated	Oxygen gas.
— empyreal	
— vital	
— pure	
— impure or vitiated	Nitrogen gas, or azote, or azotic gas.
— burnt	
— phlogisticated	
— inflammable	Hydrogen gas.
— marine acid	Muriatic acid gas.
— dephlogisticated marine acid	Oxygenized muriatic acid gas.

* The term *gas* is now used as a general name for all kinds of air, except atmospheric air.

Old names.	*New names.*
Air, hepatic — fetid of sulphur	Sulphuretted hydrogen gas.
— fixed — solid, of Hales	Carbonic acid gas.
— alkaline	Ammoniacal gas.
Algaroth, powder of	White oxide of antimony by the muriatic acid.
Alkalies, fixed	Potash and soda.
Alkali, volatile	Ammonia.
—— concrete volatile	Carbonate of ammonia.
Alkalies, caustic	Pure alkalies, or those deprived of carbonic acid.
Alkalies effervescent, or not caustic, or aerated, or mild.	Alkaline carbonates, or alkalies combined with carbonic acid.
Alkali vegetable	Potash.*
—— mineral —— marine	Soda.
—— prussian	Prussiate of potass.
Alum	Sulphate of alumine and potass.
Antimony, crude	Sulphuret of antimony.
——— diaphoretic	White oxide of antimony by the nitric acid.
Aquafortis	Nitric acid of commerce.
Aqua-regia	Nitro-muriatic acid.
Aqua ammonia pura	Ammonia.
Argil, or argillaceous earth,	Alumine.
Barilla	Carbonate of soda.
Benzoar mineral	Oxide of antimony.
Black lead	Hyper-carburet of iron.
Blue, Prussian	Prussiate of iron.
Borax	Borate of soda.
Butter of antimony	Muriate of antimony.
Calces, metallic	Metallic oxides.
Caustic, lunar	Fused nitrate of silver.

* The *potash* of commerce, when purified, is now called potass.

Old names.	*New names.*
Ceruse	White oxide of lead by the acetous acid.
Ceruse of antimony	White oxide of antimony by precipitation.
Chalk	Carbonate of lime.
Charcoal, pine	Carbon.
Cinnabar	Red sulphuretted oxide of mercury.
Colthothar of vitriol	Red oxide of iron, by the sulphuric acid.
Copper, acetated	Acetate of copper.
Copperas, green	Sulphate of iron.
—— blue	—— of copper.
Cream of tartar	Supertartrate of potass.
Earth, calcareous	Lime.
—— aluminous	Alumine.
—— of alum	
—— siliceous	Silex.
—— ponderous	Barytes.
—— magnesian	Magnesia.
—— muriatic	
Egg, white of	Albumen.
Elastic gum	Caoutchouc.
Indian rubber	
Emetic tartar	Antimoniated tartrate of potass.
Essences	Volatile oil.
Ethiops martial	Black oxide of iron.
—— mineral	Black sulphuretted oxide of mercury.
—— per se	
Flowers, metallic	Sublimated metallic oxides.
—— of sulphur	—— sulphur.
Fluors	Fluates.
Glass of bismuth	Vitreous oxide of bismuth.
Glue or jelly	Gelatine.
Glutinous matter	Gluten.
Gypsum	Sulphate of lime.
Hepars	Sulphurets.

Old names.	*New names.*
Heat, latent, or matter of heat	Caloric.
Hermus mineral	Red sulphuretted oxide of antimony.
Lapis infernalis	Fused nitrate of silver.
Leys	Solutions of alkalies.
Liquor silicum	Solutions of siliceous potash.
—— of flints	
Litharge	Litharge, or semi-vitreous oxide of lead.
Liver of sulphur, alkaline	Sulphuret of potash.
Liver of sulphur, calcareous	Sulphuret of lime.
Luna cornea	Muriate of silver.
Magistery of bismuth	Oxide of bismuth by the nitric acid.
—— of lead	Precipitated oxide of lead.
Magnesia alba	Carbonate of magnesia.
——aerated	
——black	Black oxide of manganese.
Masticot	Yellow oxide of lead.
Matter, amylacious	Fecula, or starch.
Mephitis	Nitrogen.
Minium	Red oxide of lead.
Mother waters	Deliquescent saline residues
Nitre	Nitrate of potash.
Saltpetre	
Nitres	Nitrates.
Oils, fat	Fixed oils.
— essential	Volatile oils.
— ethereal	
— of tartar per deliquium	Solution of carbonate of potash.

Phlogiston, an imaginary principle, adopted by Stahl and his followers, to account for the phenomena of combustion. Its existence having never been proved, it has no name in modern science.*

* In general, the works in which it is used, may be understood by substituting the term "hydrogen," instead of it; and by "dephlogisticated," understanding free from hydrogen.

Old names.	*New names.*
Phosphoric salts	Phosphates.
Plumbago	Hyper-carburet of iron.
Precipitate, red	Red oxide of mercury by the nitric acid.
——— per se	Red oxide of mercury by fire.
Principle, astringent	Gallic acid.
——— tanning	Tannin.
——— acidifying	Oxygen.
——— inflammable,	identical with Phlogiston.
Pyrites of copper	Sulphuret of copper.
——— martial	——— of iron.
——— factitious	——— of iron.
Reulgar	Red sulphureted oxide of arsenic.
Regulus of a metal	The metal in a state of purity
Rust of copper	Green oxide of copper.
—— of iron	Carbonate of iron.
Saffron of mars	Red oxide of iron.
Sal ammoniac	Muriate of ammonia.
— polychrest	Sulphate of potass.
Salt, common or sea	Muriate of soda.
—— febrifuge of Sylicius	Muriate of potass.
Salt, fusible of urine	Phosphate of soda and ammonia.
Salt glaubers	Sulphate of soda.
—— epsom	——— of magnesia.
—— of Sorel	Super-oxolate of potass.
—— of wormwood	Carbonate of potass.
—— vegetable	Tartrate of potass.
—— sedative	Boracic acid.
—— Sthal's sulphureous	Sulphate of potash.
Selenite	Sulphate of lime.
Spar, calcareous	Crystallized carbonate of lime.
—— fluor	Fluate of lime.
—— ponderous	Sulphate of barytes.
Spirit, ardent	Alcohol.
—— of nitre	Nitric acid.
—— of nitre, fuming	Nitrous acid.
—— of salt	Muriatic acid.
—— of sal ammoniac	Ammonia.

Old names.	*New names.*
Spirit of vitriol	Sulphuric acid.
—— of wine	Alcohol.
Spiritus rector	Aroma.
Sublimate, corrosive	Corrosive muriate of mercury.
Sugar of lead	Acetate of lead.
Sulphur, alkaline liver of	Sulphuret of potass, soda, &c.
——— metallic liver of	Alkaline sulphurets containing metals.
Tartar	Super-tartrate of potass.
——— emetic	Antimoniated tartrate of potass.
——— vitriolated	Sulphate of potash.
Tartars	Tartrates.
Tinctures, spirituous	Resins dissolved in alcohol.
Turbith mineral	Yellow oxide of mercury by sulphuric acid.
Verdigris, or rust of copper	Green oxide of copper.
——— exposed to the air	
——— of the shops	Acetate of copper mixed with oxide.
——— distilled	Crystallized acetate of copper.
Vinegar, distilled	Acetous acid.
——— radical	Acetic acid.
Vitriol, blue or roman	Sulphate of copper.
——— green	——— of iron.
——— martial	
——— white	——— of zinc.
Vitriols	Sulphates.
Water, acreted or acidulated.	Water impregnated with carbonic acid.
——— hepatic	Water impregnated with sulphuretted hydrogen.

CHEMICAL TERMS EXPLAINED.

To the preceding view of chemical nomenclature, the following explanations of terms will not perhaps be an unacceptable addition.

Affinity, (a proximity of relationship.) The term affinity is used indifferently with attraction. See *Attraction.*

Air. This term, till lately, was used as the generic name for such invisible and exceedingly rare fluids as possess a very high degree of elasticity, and are not condensible into the liquid state by any degree of cold hitherto produced; but, as this term is commonly employed to signify that compound of aeriform fluids which constitutes our atmosphere, it has been deemed advisable to restrict it to this signification, and to employ as the generic term, the word GAS, for the different kinds of air, except what relates to our atmospheric compound. The atmosphere may be said, in general terms, to consist of oxygen and nitrogen; but atmospheric air, even when purest, always contains a small proportion of other principles. Murray states its exact composition as follows:—

	By measure.	By weight.
Nitrogen gas,	77.5	75.55
Oxygen gas,	21.0	23.32
Aqueous vapour,	1.42	1.03
Carbonic acid gas,	.08	.10
	100.0	100.0

Alchemy. That branch of chemistry which relates to the transmutation of metals into gold; the forming a panacea or universal remedy, an alcahest, or universal

menstruum, an universal ferment, and many other absurdities.

Alchemist. One who practises the mystical art of alchemy.

Alkali, or ant-acid. Any substance which, when mingled with acid, produces fermentation. (See *Alkalies.*)

Alloy. 1. Where any precious metal is mixed with another of less value, the assayers call the latter the alloy, and do not in general consider it in any other point of view, than as debasing or diminishing the precious metal.

2. Philosophical chemists have availed themselves of this term, to distinguish all metallic compounds in general. Thus brass is called the alloy of copper and zinc; bell-metal, an alloy of copper and tin.

Every alloy is distinguished by the metal which predominates in its composition, or which gives it its value. Thus English jewelry, trinkets, are ranked under alloys of gold, though most of them deserve to be placed under the head of copper. When mercury is one of the component metals, the alloy is called *amalgam.* Thus we have an amalgam of gold, silver, tin, &c. Since there are about thirty different permanent metals, independent of those evanescent ones that constitute the basis of the alkalies and earths, there ought to be about 870 different species of binary alloys. But only 132 species have been made and examined. Some metals have so little affinity for others, that as yet no compound of them has been effected, whatever pains have been taken. Most of these obstacles to alloying, arise from the difference in fusibility and volatility. Yet a few metals, the melting point of which is nearly the same, refuse to unite. It is obvious that two bodies will not combine, unless their affinity or reciprocal attraction be stronger than the cohesive attraction of their individual particles. To overcome this cohesion of the solid bodies, and render affinity predominant, they must be penetrated by caloric. If one be very difficult of fusion, and the other very volatile, they will not unite unless the reciprocal

attraction be exceedingly strong. But if that degree of fusibility be almost the same, they are easily placed in the circumstances most favourable for making an alloy If we are, therefore, far from knowing all the binary alloys which are possible, we are still further removed from knowing all the triple, quadruple, &c. which may exist. It must be confessed, moreover, that this department of chemistry has been imperfectly cultivated.

Analysis. The resolution, by chemistry, of any matter into its primary and constituent parts. The processes and experiments which chemists have recourse to, are very numerous and diversified, yet they may be reduced to two species, which comprehend the whole art of chemistry. The first is, *analysis*, or decomposition; the second, *synthesis*, or composition. In *analysis*, the parts of which bodies are composed, are separated from each other: thus if we reduce cinnabar, which is composed of sulphur and mercury, and exhibit those two bodies in a separate state, we say we have decomposed or analyzed cinnabar. But if, on the contrary, several bodies be mixed together, and a new substance be produced, the process is then termed chemical composition, or *synthesis*. thus, if by fusion and sublimation, we combine mercury with sulphur, and form cinnabar, the operation is termed chemical composition, or composition by synthesis. Chemical analysis consists of a great variety of operations. In these operations, the most extensive knowledge of such properties of bodies as are already discovered, must be applied, in order to produce simplicity of effect and certainty in the results. Chemical analysis can hardly be executed with success, by one who is not in possession of a considerable number of simple substances, in a state of great purity, many of which, from their effects, are called reagents. The word analysis, is often applied by chemists to denote that series of operations by which the component parts of bodies are determined, whether they be merely separated or exhibited apart from each other; or whether these distinctive properties be exhibited by causing them to enter into a new combination, without

the perceptible intervention of a separate state; and in the chemical examination of bodies, analysis or separation can scarcely ever be effected, without synthesis taking place at the same time.

Apparatus. This term is applied to the instruments, the preparation, and arrangements, of every thing necessary in the performance of any operation, medical, surgical, or chemical.

Assay. This operation consists in determining the quantity of valuable or precious metal contained in any mineral or metallic mixture, by analyzing a small part thereof. The practical difference between the analysis and assay of an ore, consists in this:—The analysis, if properly made, determines the nature and qualities of all the parts of the compound; whereas, the object of the assay consists in ascertaining how much of the par ticular metal in question may be contained in a certain determinate quantity of the material under examination. Thus, in the assay of gold or silver, the baser metals are considered as of no value or consequence; and the problem to be resolved is simply, how much of each is contained in the ingot or piece of metal intended to be assayed.

Astringent. That which, when applied to the body, renders the solids denser and firmer, by contracting their fibres, independently of their living, or muscular power. Astringents thus serve to diminish excessive discharges; and by causing greater compression of the nervous fibrillæ, may lessen morbid sensibility or irritability. Hence they may tend indirectly to restore the strength, when impaired by these causes. The chief class of these articles are the acids, alum, lime-water, chalk, certain preparations of copper, zinc, iron, and lead; the gallic acid, which is commonly found united with the true astringent principle, was long mistaken for it. Seguin first distinguished them; and, from the use of this principle in tanning skins, has given it the name of *tannin*. Their characteristic differences are, the gallic acid forms

a black precipitate with iron; the astringent principle forms an insoluble compound with albumen.

Atmosphere. The elastic invisible fluid which surrounds the earth to an unknown height, and encloses it on all sides. (See *Air.*)

Atoms. In the chemical combination of bodies with each other, it is observed that some unite in all proportions; others in all proportions as far as a certain point beyond which combination no longer takes place: there are also many examples in which bodies unite in one proportion only, and others in several proportions; and these proportions are definite, and in the intermediate ones no combination ensues. And it is remarkable, that when one body enters into combination with another, in several different proportions, the numbers indicating the greater proportions are exact simple multiples of that denoting the smallest proportion. In other words, if the smallest portion in which B. combines with A. be denoted by 10, A. may combine with twice 10 of B. or with three times 10, and so on; but with no intermediate quantities. Examples of this kind have of late so much increased in number, that the law of simple multiples bids fair to become universal with respect at least to chemical compounds, the proportions of which are definite. By the term atoms, we are to understand the smallest particles of which bodies are composed. An atom, therefore, must be mechanically indivisible, and of course a fraction of an atom cannot exist, and is a contradiction in terms. Whether the atoms of different bodies be of the same size, or of different sizes, we have no sufficient evidence. The probability is, that the atoms of different bodies are of unequal sizes; but it cannot be determined whether their sizes bear any regular proportion to their relative weights. We are equally ignorant of their shape; but it is probable they are spherical. Sir Isaac Newton closes an admirable disquisition on the nature, laws, and constitution of matter, by stating the great probability that God in the beginning formed matter into solid, massive, impenetrable, moveable particles or atoms, of such

sizes and figures, and with such other properties, and in such proportion to space, as most conduced to the end for which he formed them; and that these primitive particles, being absolute solids, are incomparably harder than any of the bodies compounded of them, even so hard as to be incapable of wearing or breaking in pieces, nothing but Infinite Power being able to destroy what Infinite Power made one in the first creation. That nature may be lasting, the changes of corporal things are to be attributed only to the various separations and new associations of these permanent particles; and when compound bodies break, it is not in the midst of solid particles, but where these are laid together, and touch only in a few points.

Attraction. The terms attraction, or affinity, and repulsion, in the language of modern philosophers, are employed merely as the expression of general facts, that the masses or particles of matter have a tendency to approach and unite to, or to recede from one another, under certain circumstances. The term attraction is used synonymously with affinity.

All bodies have a tendency or power to attract each other, more or less, and it is this power which is called attraction.

Attraction is mutual: it extends to indefinite distances. All bodies, whatever, as well as their component elementary particles, are endued with it. It is not annihilated, at however great a distance we suppose them to be placed from each other; neither does it disappear, though they be arranged ever so near each other.

The nature of this reciprocal attraction, or at least the cause which produces it, is altogether unknown to us. Whether it be inherent in all matter, or whether it be the consequence of some other agent, are questions beyond the reach of human understanding; but its existence is nevertheless certain.

The instances of attraction which are exhibited by the phenomena around us, are exceedingly numerous, and continually presenting themselves to our observation.

The effect of gravity, which causes the weight of bodies, is so universal, that we can scarcely form an idea how the universe could exist without it. Other attractions such as those of magnetism and electricity, are likewise observable; and every experiment in chemistry tends to show, that bodies are composed of various principles or substances, which adhere to each other with various degrees of force, and may be separated from each other by known methods.

The species of attraction called *chemical attraction*, is also not unfrequently designated by the appellation of the *attraction of composition*, or *chemical affinity*. This kind of attraction takes place only between the elementary particles of different bodies; and every integrant part of the compound which results from its effects, differs in its properties from any of its component parts It is by this change of properties that chemical combination, or the action of chemical attraction, is distinguished from mere mechanical mixture. By mechanical mixture, it is obvious, that gold, however minutely divided, could not exist in every part of a fluid lighter than itself; but when the fluid has a chemical attraction for gold, the solution is homogeneous, and incapable of separation by the filter, or any other mechanical means.

In order to bring affinity fully into action, it is in general necessary that one or both of the bodies presented to each other, should be in a fluid state; or that heat should be applied to disunite the particles, by lessening the attraction of cohesion; for mechanical subdivision or comminution never extending to the separation of the ultimate particles of bodies, seldom allows that liberty of action, in the exercise of which affinity appears. Instances, however, occur, in which two solids produce a fluid: thus, if pounded ice and muriate of soda be mixed together, a fluid brine will be attained, unless the temperature, at the time of the experiment, is lower than that at which brine freezes, and this is thirty-eight degrees below the freezing point of water.

Dr. Black discovered that whenever a body changes

its state by chemical affinity, its temperature is changed at the same time, either lessened or increased.

The discoveries of Sir H. Davy, seem to establish as a fact, that no chemical affinity takes place between the particles of bodies, unless they be in an opposite electrical state; and that by artificially changing the electrical state of bodies, their affinities may be modified or destroyed.

The action of the affinity of composition, in different cases, has been distinguished in the following manner:

1. When two principles, united together, are separated by means of a third, we are said to have an example of *simple affinity.* This simple affinity, Bergman called *simple elective attraction*, an expression still much used by chemists.

2. When a body, composed of two others, cannot be destroyed by a third or fourth body separately applied, yet is destroyed or decompounded by the action of a third and fourth bodies, if these be united before they are added to it; the example in this case, and when any greater number of bodies are employed, is called *compound affinity*, or *compound elective attraction.*

3. When two bodies which have no perceptible action on each other, unite by the addition of a third body, the example is called *intermediate affinity.* It is instanced in the union of oil and water, by the means of an alkali.

Tables of elective attraction have been constructed, which are of singular service in directing the attention of the chemist to the effects of substances on each other: we shall advert to them when we have considered the properties of substances themselves.

Bases. This term is usually applied to alkalies, earths, and metallic oxides, in their relations to the acids and salts. It is sometimes also applied to the particular constituents of an acid or oxide, on the supposition that the substance combined with the oxygen, &c. is the basis of the compound to which it owes its particular qualities. This notion seems unphilosophical, as these qualities de-

pend as much on the state of combination as on the nature of the constituent.

Bi. This term is used in anatomy, botany, and chemistry: in composition, it signifies twice or double.

Calcareous. Substances which partake somewhat of the nature and qualities of *calx*.

Calcination. The fixed residues of such matters as have undergone combustion are called cinders, in common language, and calxes, but now more commonly oxides, by chemists; and the operation, when considered with regard to these residues, is termed calcination. In this general way, it has likewise been applied to bodies not really combustible, but only deprived of some of their principles by heat. Thus we hear of the calcination of chalk, to convert it into lime by driving off the carbonic acid and water; of gypsum, or plaster-stone, of alum, of borax, and other saline bodies, by which they are deprived of their water of crystallization; of bones, which lose their volatile parts by this treatment, and of various other bodies. It is also applied to metals, in their combination with oxygen, by means of heat.

Caloric. That which produces the sensation of heat. (See *Caloric.*)

Carburet. A combination of charcoal with any other substance: thus carburetted hydrogen is hydrogen holding carbon in solution; carburetted iron is steel, &c.

Caustic. (To burn; because it always causes a burning sensation.) A substance which always causes a burning sensation, and has so strong a tendency to combine with organized substances, as to destroy their texture.

Cawk. A term by which the miners distinguish the opaque specimens of sulphate of barytes.

Cementation. A process in which a body in a solid state, is surrounded by another in powder, and exposed for some time in a close vessel to a degree of heat which will not fuse either of the bodies. Iron thus surrounded by charcoal is converted into steel; and copper, by cementation with calamine and charcoal, is converted into

brass; green bottle-glass is converted into porcelain by cementation with sand, &c.

Chlorate. A compound of chloric acid with a salifiable basis.

Coagulation. The separation of the coagulable particles, contained in any fluid, from the more thin and not coagulable particles: thus, when milk curdles, the coagulable particles form the curd; and when acids are thrown into any fluid containing coagulable particles, they form what is called *coagulum.*

Combination. The intimate union of the particles of different substances by chemical attraction, so as to form a compound possessed of new and peculiar properties.

Combustion. The union of a body with oxygen accompanied by the evolution of light and heat; therefore every body which is capable of forming this union, is called a combustible. (See *Combustion.*)

Compound. The result or effect of a composition of different things; or that which arises from them. It stands opposed to simple.

Concentration. A process by which the watery part of any fluid is separated, by evaporation; or the volatilizing of part of the water of fluids, in order to improve their strength. The matter, therefore, to be concentrated, must be of superior fixity to water. This operation is performed on some acids, particularly the sulphuric and phosphoric. It is also employed in solutions of alkalies and neutral salts.

Concretion. The condensation of any fluid substance into a more solid consistence.

The growing together of parts which, in a natural state, are separate.

Condensation. The thickening of any fluid.

Congelation. The change of liquid bodies, which takes place when they pass to a solid state, by losing the caloric which kept them in a fluid state.

Crystallization. A property by which crystallizable bodies tend to assume a regular form, when placed favourable to that particular disposition of their particles. Al-

most all minerals possess this property, but it is most eminent in saline substances. The circumstances which are favourable to crystallization of salts, and without which it cannot take place, are two: 1. Their particles must be divided and separated by a fluid, in order that the corresponding faces of those particles may meet and unite. 2. In order that this union may take place, the fluid which separates the integrant parts of the salt must be gradually carried off, so that it may no longer divide them. (See *Crystallization.*)

Cupellation. The purifying of perfect metals by means of an addition of lead, which, at a due heat, becomes vitrified, and promotes the vitrification and calcination of such imperfect metals as may be in the mixture, so that these last are carried off in the fusible glass that is formed, and the perfect metals are left nearly pure. The name of this operation is taken from the vessels made use of, which are called cupels.

Decantation. The separation of a fluid from the undissolved particles or solids which it contains. This is done by leaving the fluid at rest in a conical vessel; and when the foreign matter has deposited itself at the bottom, the fluid is gently poured off, in order not to disturb the sediment. When the matter deposited is light, and apt to mix with the fluid, or when the vessel containing it cannot be conveniently moved, a siphon is employed to draw it off. A thick woollen thread steeped in the liquor, and inclining over the edge of the vessel, makes a very good siphon for this purpose.

Decoction. A fluid holding in solution some substance which it has obtained by boiling: thus we say a decoction of bark, &c. When the preparation is made by cold water, it is called an *infusion.*

Decomposition. The substances of which any compound body is formed, are called its component or constituent parts; and when these are separated from each other, the body is said to be decomposed, or to have undergone decomposition. Thus soap is compounded of oil and an alkali; and when the oil and alkali are separated from each other, the soap is decomposed.

Decrepitation. The small and successive explosions which take place in many chemical operations, as when salts are exposed to heat.

Deflagration. A chemical term, chiefly employed to express the burning or setting fire to any substance; as nitre, sulphur, &c.

Deplegmation. The operation of rectifying or freeing spirits from their watery parts, or any method by which bodies are deprived of their water.

Dephlogisticated. A term of the old chemistry, implying, deprived of phlogiston, or the inflammable principle.

Deliquescence. The state of a salt which becomes fluid by its absorption of moisture from the atmosphere.

Desiccation. (Drying.) The expelling or evaporating of humid matter from any substance, by means of heat.

Descensus. Chemists call this a distillation by descent, when the fire is at the top and round the vessel, the orifice of which is at the bottom.

Detonation. An explosion caused by a sudden expansion and combustion of certain substances; it differs from decrepitation in being more rapid, and louder.

Digestion. The slow action of a solvent upon any substance, whether assisted by heat or not.

Distillation. The separation by heat of a volatile fluid from other substances which are fixed; or the separation of substances more or less volatile from each other. (See *Distillation.*)

Ductility. A property by which bodies are elongated by repeated or continued pressure. It is peculiar to metals. Most authors confound the words malleability, laminability, and ductility, together, and use them in a loose indiscriminate way; but they are very different. Malleability is the property of a body which enlarges one or two of its three dimensions by a blow or pressure very suddenly applied. Laminability belongs to bodies extensible in dimension by a gradually applied pressure; and ductility is properly to be attributed to such bodies as can be rendered longer and thinner by drawing them

through a hole of less area than the transverse section of the body so drawn.

Ebullition. This consists in the change which a fluid undergoes from a state of liquidity to that of an elastic fluid, in consequence of the application of heat, which dilates and converts it into vapour.

Effervescence. The bubbling and noise produced by the escape of volatile parts from a fluid, or the agitation which is produced by mixing substances together, which cause the evolution of a gas.

Efflorescence. That which takes place when bodies spontaneously become converted into a dry powder. It is almost always occasioned by the loss of the water of crystallization in saline bodies.

Elastic. Having the power of returning to the form from which it has been forced to deviate, or from which it is withheld; thus a blade of steel is said to be elastic, because if it is bent to a certain degree, and then let go, it will of itself return to its former situation; the same will happen to the branch of a tree, a piece of Indian rubber, &c.

Eliquation. An operation in which a substance is separated from another which is less fusible, by the application of a degree of heat which will fuse only the former; thus copper may be separated from its alloy with lead, with a degree of heat which is sufficient only to melt the lead.

Equivalents. A term introduced into chemistry by Dr. Wollaston, to express the system of definite ratios, in which the corpuscular objects of this science reciprocally unite.

Essence. Several of the volatile or essential oils are called by this name.

Ethereal. A term applied to any highly rectified or essential oil, or spirit.

Evaporation. A chemical process usually performed by applying heat to any compound substance, in order to dispel the volatile parts. It differs from distillation in its object, which chiefly consists in preserving the more

fixed matters, while the volatile substances are dissipated and lost. And the vessels are accordingly different: evaporation being made in open shallow vessels, and distillation in an apparatus nearly closed from the external air.

The degree of heat must be duly regulated in evaporation. When the fixed and more volatile parts do no liffer greatly in their tendency to fly off, the heat mus be very carefully adjusted; but in other cases this is less necessary. As evaporation consists in the assumption of the elastic form, its rapidity will be in proportion to the degree of heat, and the diminution of the pressure of the atmosphere.

Extract. The solid matter obtained by evaporating the watery parts of a decoction or infusion.

Fermentation. A slow motion of the intestine particles of a mixed body.

Filtration. An operation by which a fluid is mechanically separated from consistent particles mixed with it. It does not differ from straining.

An apparatus fitted for this purpose is called a filter. The form of this is various, according to the intention of the operator. A piece of tow, or wool, or cotton, stuffed into the pipe of a funnel, will prevent the passage of grosser particles, and by that means render the fluid clearer which comes through. Sponge is still more effectual. A strip of linen rag wetted and hung over the side of the vessel containing the fluid, in such a manner that one end of the rag may be immersed in the fluid, and the other end may remain without, below the surface, will act as a siphon, and carry over the clearer portion. Linen or woollen stuffs may either be fastened over the mouths of proper vessels, or fixed to a frame like a sieve, for the purpose of filtering. All these are more commonly used by cooks and apothecaries than by philosophical chemists, who, for the most part, use the paper called cap paper, made up without size.

As the filtration of considerable quantities of fluid could not be effected at once without breaking the pa-

per, it is found requisite to use a linen cloth, upon which the paper is applied and supported.

Precipitates and other pulverulent matters are collected more speedily by filtration than by subsidence. But there are many chemists who disclaim the use of this method, and avail themselves of the latter only, which is certainly more accurate, and liable to no objection, where the powders are such as will admit of edulcoration and drying in the open air.

Some fluids, as turbid water, may be purified by filtering through sand. A large earthen funnel, or stone bottle with the bottom beaten out, may have its neck loosely stopped with small stones, over which smaller may be placed, supporting layers of gravel increasing in fineness, and lastly covered with a few inches of fine sand, all thoroughly cleaned by washing. This apparatus is superior to a filtering-stone, as it will clean water in large quantities, and may be readily renewed when the passage is obstructed, by taking out and washing the upper stratum of sand.

A filter for corrosive liquors may be constructed, on the same principles, of broken and pounded glass. (*Ure's Chem. Dict.*)

Fixed. An epithet descriptive of such bodies as so far resist the action of heat as not to rise in vapour. It is the opposite of volatile; but it must be observed, that the fixity of bodies is merely a relative term, as an adequate degree of heat will dissipate all.

Fluate. A compound of the fluoric acid with salifiable bases: thus, fluate of lime, &c.

Fluid. A fluid is that, the particles of which so little attract each other, that when poured out, it drops, and adapts itself in every respect to the form of the vessel containing it. (See *Fluid.*)

Flux. A general term made use of to denote any substance or mixture added to assist the fusion of metals.

Fluxion. A term mostly applied to signify the change of metals, or other bodies, from the solid into a fluid state, by the application of heat. (See *Fusion.*)

Fulmination. A still more violent and sudden explosion than detonation.

Fusion. A chemical process, by which bodies are made to pass from a solid to a fluid state by means of the application of heat. The chief objects susceptible of this operation are salts, sulphur, and metals. Salts are liable to two kinds of fusion: the one, which is peculiar to saline matters, is owing to water contained in them, and is called *aqueous fusion;* the other, which arises from the heat alone, is known by the name of *igneous fusion.*

Gas. Elastic fluid; aeriform fluid. This term is applied to all permanently elastic fluids, simple or compound, except the atmosphere, to which the term *air* is appropriated. (See *Gas.*)

Ide. This terminal is affixed to oxygen, chlorine, and iodine, when they enter into combination with each other, or with simple combustibles or metals, in proportions not forming an acid; thus *ox-ide* of chlorine, *ox-ide* of nitrogen, *chlor-ide* of sulphur, *iod-ide* of iron.

Incineration. The burning of vegetable or animal substances, to obtain their ashes, or fixed residue, which is lixiviated.

Inflammable. Chemists distinguish by this term such substances as burn with facility, and flame in an increased temperature.

Infusion. A process that consists in pouring water of any required degree of temperature on such substances as have a loose texture; as thin bark, wood in shavings or small pieces, leaves, flowers, &c., and suffering it to stand a certain time. The liquor obtained by the above process is called an infusion.

Iodate. A compound of iodine with oxygen, and a metallic basis.

Iodide. A compound of iodine with a metal; as *Iodide of pot-assium.*

Lacquer. A solution of lac in alcohol.

Lactate. A definite compound formed by the union of the acid of whey, or lactic acid, with salifiable bases; thus, lactate of potassa, &c.

Levigation. The reduction of a hard substance, by triture, to an impalpable powder.

Liquefaction. A term sometimes used synonymously with *fusion*, in others with the word deliquescence, and in others with the word *solution*.

Lixiviation. The application of water to the fixed residues of bodies, for the purpose of extracting the saline parts, which dissolve in the water, and afterwards crystallize on evaporation.

Maceration. This term implies an infusion either with or without heat, wherein the ingredients are intended to be almost wholly dissolved in order to extract their virtues.

Magistery. An obsolete term used by ancient chemists to signify a peculiar and secret method of preparing any medicine, as it were by a masterly process. The term was also long applied to all precipitates.

Martial. Sometimes used to express preparations of iron, or such as are impregnated therewith; as the martial regulus of antimony, &c.

Menstruum. All liquors are so called which are used as dissolvents, or to extract the virtues of ingredients by infusion, decoction, &c.

Mineralize. Metallic substances are said to be mineralized when deprived of their usual properties by combination with some other substance.

Mother-water. When sea-water, or any other selection containing various salts, is evaporated, and the crystals taken out, there always remains a fluid containing deliquescent salts, and the impurities, if present. This is called the mother-water.

Neutral. A term applied to saline compounds of an acid and an alkali, which are so called, because they do not possess the characters of acid or alkaline salts; such are Epsom-salts, nitre, and all the compounds of alkalies with acids.

Neutralization. When acid and alkaline matter are combined in such proportions, that the compound does not change the colour of litmus or violets, they are said to be neutralized.

Oxidation. The process of converting metals and other substances into oxides, by combining with them a certain portion of oxygen. It differs from acidification in the addition of oxygen not being sufficient to form an acid with the substance oxidized.

Oxide. A substance combined with oxygen without being in the state of an acid. Many substances are susceptible of several stages of oxidizement, on which account chemists have employed various terms to express the characteristic distinctions of the several oxides. The specific name is often derived from some external character, chiefly the colour; thus we have the black and red oxides of iron, and of mercury; the white oxide of zinc: but in most instances the denominations proposed by Dr. Thompson are adopted. When there are several oxides of the same substance, he proposes the terms *protoxide*, *deutoxide*, *tritoxide*, signifying the first, second, and third stage of oxidizement. Or if two oxides only are known, he proposes the appellation of *protoxide* for that at the minimum, and of *peroxide* for that at the maximum, of oxidation. The compounds of oxides and water in which the water exists in a condensed state are termed *hydrates*, or hydroxures.

Oxygenation. This word is often used instead of oxidation, and frequently confounded with it; but it differs in being of more general import, as every union with oxygen, whatever the product may be, is an oxygenation; but oxidation takes place only when an oxide is formed.

Oxyiode. A term applied by Sir H. Davy to the triple compounds of oxygen, iodine, and the metallic bases. Lussac calls them *iodates*.

Petrifactions. Stony matters deposited either in the way of incrustation, or within the cavities of organized substances, are called petrifactions. Calcareous earth being universally diffused, and capable of solution in water, either alone or by the medium of carbonic acid or sulphuric acid, which are likewise very abundant, is deposited whenever the water or the acid becomes dissipated. In this way we have incrustations of limestone

or of selenite in the form of stalactites or dropstones from the roofs of caverns, and in various other situations.

The most remarkable observations relative to petrifactions are thus given by Kerwan:

1. That those of shells are found on, or near, the surface of the earth; those of fish, deeper; those of wood, deepest. Shells in specie are found in immense quantities at considerable depths.

2. That those organic substances that resist putrefaction most, are frequently found petrified; such as shells, and the harder species of woods: on the contrary, those that are aptest to putrefy are rarely found petrified; as softer parts of animals, fish, &c.

3. That they are most found in strata of marl, chalk, limestone, or clay, seldom in sandstone, still more rarely in gypsum; but never in gneiss, granite, basalts, or shale; but they sometimes occur in pyrites, and ores of iron, copper, and silver, and almost always consist of that species of earth, stone, or other mineral that surrounds them, sometimes of silex, agate, or cornelian.

4. That they are found in climates where their originals could not have existed.

5. That those found in slate or clay are compressed and flattened.

Phlegm. In chemistry this term means the water from distillation.

Phlogiston. The supposed general inflammable principle of Stahl, who imagined it was pure fire, or the matter of fire fixed in combustible bodies, in order to distinguish it from fire in action, or in a state of liberty.

Phosphate. A salt formed by the union of phosphoric acid with salifiable bases; thus, *phosphate of ammonia, phosphate of lime,* &c.

Precipitation. When two bodies are united, for instance, an acid and an oxide, and a third body is added, such as an alkali, which has a greater affinity with the acid than the metallic oxide has, the consequence is, that the alkali combines with the acid, and the oxide thus deserted appears in a separate state, at the bottom

of the vessel in which the operation is performed. This decomposition is commonly known by the name of *precipitation*, and the substance that sinks is named a *precipitate*. The substance, by the addition of which the phenomenon is produced, is denominated the *precipitant*.

Principles. Substances or particles, which are composed of two or more elements; thus water, gelatine, sugar, fibrine, &c., are the principles of many bodies. These principles are composed of elementary bodies, as oxygen, hydrogen, azote, &c., which are undecomposable.

Putrefaction. (To become rotten, to dissolve.) Putrid fermentation. The spontaneous decomposition of animal and vegetable matters, that exhale a fœtid smell. The solid and the fluid matters are resolved into gaseous compounds and vapours, which escape and unite an earthy residuum. The requisites to this process are:—1. A certain degree of humidity. 2. The access of atmospheric air. 3. A certain degree of heat. Hence the abstraction of the air and water, or humidity, by drying, or its fixation by cold, by salt, sugar, spices, &c., will counteract the process of putrefaction, and favour the preservation of food, on which principle some patents have been obtained.

Pyrites. (So called because it strikes fire with steel.) Native compounds of metal with sulphur.

Radical. This term is applied to that which is considered as constituting the distinguishing part of an acid, by its union with the acidifying principle or oxygen, which is common to all acids. Thus sulphur is the radical of sulphuric and sulphurous acids. It is sometimes called the base of the acid; but base is a term of more extensive application.

Rancidity. The change which oils undergo by exposure to air, which is probably an effect analogous to the oxidation of metals.

Reagent—Test. A substance used in chemistry to detect the presence of other bodies. In the application of tests, there are two circumstances to attend to: viz to avoid deceitful appearances, and to have good tests.

The principal tests are the following:

1. *Litmus.* The purple of litmus is turned to red by every acid; so that this is the test generally made use of to detect the excess of acid in every fluid. It may be used either by dipping into the water a piece of paper stained with litmus, or by adding a drop of the tincture to the water to be examined, and comparing its hue with that of an equal quantity of the tincture in distilled water.

Litmus already reddened by an acid, will have its purple restored by an alkali; and thus it may also be used as a test for alkalies, but it is much less active than other direct alkaline tests.

2. *Red cabbage* has been found by Watt to furnish as delicate a test for acids as litmus, and to be still more sensible for alkalies. The natural colour of an infusion of this plant is blue, which is changed to a red by acids, and to a green by alkalies in very minute quantities.

3. *Brazil wood.* When chips of this wood are infused in warm water, they yield a red liquor, which readily turns blue by alkalies, either caustic or carbonated. It is also rendered blue by the carbonated earths held in solution by carbonic acid, so that it is not an unequivocal test of alkalies till the earthy carbonates have been precipitated by boiling. Acids change to yellow the natural red of Brazil wood, and restore the red when changed by alkalies.

4. *Violets.* The delicate blue of the common scented violet is readily changed to green by alkalies, and this affords a delicate test for these substances. Syrup of violets is generally used as it is at hand, being used in medicine. But a tincture of this flower will answer as well.

5. *Turmeric.* This is a very delicate test for alkalies, and on the whole, perhaps, is the best. The natural colour, either in watery or spirituous infusion, is yellow, which is changed to a brick or orange red by alkalies, caustic or carbonated, but not by carbonated earths, on which account it is preferable to Brazil wood. The pure

earths, such as lime and barytes, produce the same change.

6. *Rhubarb.* Infusion or tincture of rhubarb undergoes a similar change with turmeric, and is equally delicate.

7. *Sulphuric acid.* A drop or two of concentrated sulphuric acid, added to water that contains carbonic acid, free or in combination, causes the latter to escape with a pretty brisk effervescence, whereby the presence of this gaseous acid may be detected.

8. *Nitric and oxymuriatic acid.* A peculiar use attends the use of these acids in the sulphuretted waters, as the sulphuretted hydrogen is decomposed by them, its hydrogen absorbed, and the sulphur separated in its natural form.

9. *Oxalic acid and oxalate of ammonia.* These are the most delicate tests for lime and all soluble calcareous salts. Oxalate of lime, though nearly insoluble in water, dissolves in a moderate quantity in its own or any other acid, and hence in analysis oxalate of ammonia is often preferred, as no access of this salt can redissolve the precipitated oxalate of lime. On the other hand, the ammonia should not exceed, otherwise it might give a false indication.

10. *Gallic acid and tincture of galls.* These are tests of iron. Where the iron is in very minute quantities, and the water somewhat acidulous, these tests do not always produce a precipitate, but only a slight reddening, but their action is much heightened by previously adding a few drops of any alkaline solution.

11. *Prussiate of potassa or lime.* The presence of iron in water is indicated by these prussiates causing a blue precipitate: and if the prussiate of potassa is properly prepared, it will only be precipitated by a metallic salt, so that manganese and copper will also be detected, the former giving a white precipitate, the latter a red precipitate.

12. *Lime-water,* is the common test for carbonic acid; it decomposes all the magnesian salts, and likewise the

aluminous salts; it likewise produces a cloudiness with most of the sulphates, owing to the formation of selenite.

13. *Ammonia.* This alkali when perfectly caustic, serves as a distinction between the salts of lime and those of magnesia, as it precipitates the earth from the latter salts, but not from the former. There are two sources of error to be obviated, one is that of carbonic acid being present in the water, the other is the presence of aluminous salts.

14. *Carbonated alkalies.* These are used to precipitate all the earths; where carbonate of potassa is used, particular care should be taken of its purity, as it generally contains silex.

15. *Muriated alumine.* This test is proposed by Mr. Kirwan, to detect carbonate of magnesia, which cannot, like carbonated lime, be separated by ebullition, but remains till the whole liquid is evaporated.

16. *Barytic salts.* The nitrate, muriate, and acetate of barytes are all equally good tests of sulphuric acid in any combination.

17. *Salts of silver.* The salts of silver are the most delicate tests of muriatic acid, in any combination, producing the precipitated luna cornea. All the salts of silver likewise give a dark brown precipitate with sulphurated waters, which is as delicate a test as any we possess.

18. *Salts of lead.* The nitrate and acetate of lead are the salts of this metal employed as tests. They will indicate the sulphuric, muriatic, and boracic acids, and sulphuretted hydrogen or sulphuret of potassa.

19. *Soap.* A solution of soap in distilled water, or in alcohol, is curdled by water containing any earthy or metallic salt.

20. *Tartaric acid.* This acid is of use in distinguishing the salts of potassa (with which it forms a precipitate of cream of tartar,) from those of soda, from which it does not precipitate. The potassa, however, must exist in some quantity to be detected by the test.

21. *Nitromuriate of platium.* This sort is still mor

discriminative between potassa and the other alkalies than acid of tartar, and will produce a precipitate with a very weak solution of any salt with potassa.

22. *Alcohol.* This most useful reagent is applicable in a variety of ways in analysis. As it dissolves some substances found in fluids, and leaves others untouched, it is a means of separating them into two classes, which saves considerable trouble in the further investigation. Those salts which it does not dissolve, it precipitates from their watery solution, but more or less completely according to the alt contained, and the strength of the alcohol; and as a precipitant it also assists in many decompositions.

Rectification. (To make clean.) A second distillation, in which substances are purified by their more volatile parts being raised by heat carefully managed: thus, spirits of wine, ether, &c., are rectified by their separation from the less volatile and foreign matter which altered or debased their properties.

Reduction. When a metal is converted into an oxide by its combining with oxygen, it loses its metallic properties, and assumes the appearance of an earth; but when the oxygen with which it is combined is taken from it, all its properties as a metal are recovered; in this case the metal is said to be *reduced*, and the operation by which it is effected is called *reduction.* Revivification is a word used in the same sense as reduction, but is most commonly employed where mercury is the metal used.

Residuum, is that part of a body which remains after the most valuable parts have been separated by combustion, distillation, or sublimation.

Roasting, a preliminary operation, which prepares mineral substances for undergoing a series of succeeding ones, dividing their constituent particles, volatilizing some of their principles, and thus, in a certain degree, altering their nature. Ores are exposed to this process, with a view to separate the sulphur and the arsenic which they contain, and to diminish the cohesion of their par

ticles. Capsules of earth or iron, crucibles, and roasting pots, are the vessels in which it is usually performed; and the ore is generally exposed to the access of external air. Sometimes, however, the operation is performed in close vessels; and two crucibles, luted mouth to mouth, may be employed on such occasions. Roasting is synonymous with *torefaction* and *ustulation*.

Sal. (See *Saline.*)

Salifiable. Having the property of forming a salt. The alkalies, and those earths and metallic oxides which have the power of neutralizing acidity, entirely or in part, and producing salts, are called salifiable bases.

Saline. (From *sal*, salt.) Of a salt nature. The number of saline substances is very considerable; and they possess peculiar characters by which they are distinguished from other substances. These characters are founded on certain properties, which, it must be confessed, are not accurately distinctive of their true nature. All such substances, however, as possess several of the four following properties, are considered as saline:— 1. A strong tendency to combination, or a very strong affinity of composition. 2. A greater or lesser degree of sapidity. 3. A greater or lesser degree of solubility in water. 4. Perfect incombustibility.

Saturation. Most bodies which have a chemical affinity for each other, will only unite in certain proportions. When, therefore, a fluid has dissolved as much of any substance as it is capable of dissolving, it is said to have reached the point of saturation. Thus water will dissolve one quarter of its weight of common salt, and if more salt be added, it will sink to the bottom in a solid state. Some fluids will dissolve more of certain substances when hot than when cold. Thus water, when hot, will dissolve a much larger quantity of nitre than when cold.

Sediment. The heavy parts of liquids which fall to the bottom.

Semi. In composition, this term universally means half.

Simple. This term is applied very generally in every

department of nature, to designate that which is not compound.

Solution. The dispersion of the particles of a solid body in any fluid, in so equal a manner that the compound liquor shall be perfectly and permanently clear and transparent. This takes place when the particles of the fluid have an affinity or elective attraction for the particles of the solid. When solid particles are only dispersed in a fluid by mechanical means, it is mixture, not solution, and the compound usually opaque and muddy.

Specific gravity. The density of the matter of which any body is composed, compared to the density of another body, assumed as the standard. This standard is pure distilled water, at the temperature of 60° F. To determine the specific gravity of a solid, we weigh it, first in air, and then in water. In the latter case, it loses of its weight a quantity precisely equal to the weight of its own bulk of water; and hence, by comparing this weight with its total weight, we find its specific gravity. The rule therefore is, divide the total weight by the *loss* of weight in water, the quotient is the specific gravity. If it be a liquid or gas, we weigh it in a glass or other vessel of known capacity; and dividing the weight by the same bulk of water, the quotient is, as before, the specific gravity.

Spirit. This name was formerly given to all volatile substances collected by distillation. Three principal kinds were distinguished: inflammable or ardent spirits, acid spirits, and alkaline spirits. The word spirit is now almost exclusively confined to alcohol.

Stratification. An operation in which bodies are placed alternately in layers, in order that they may act upon each other when heat is applied to them. It is nearly the same with cementation, but cementation is more particularly applied to the cases already noted.

Sub. This term is applied when a salifiable base is predominant in a compound, there being a deficiency of the acid; a. *subcarbonate of potassa, subcarbonate of soda.*

Sublimation. A process by which volatile substances are raised by heat, and again condensed in a solid form. This process differs from evaporation only in being confined to solid substances. It is usually performed either for the purpose of purifying certain substances, and disengaging them from extraneous matters; or else to reduce into vapour, and combine, under that form, principles which would have united with greater difficulty if they had not been brought to that state of extreme division.

As all fluids are volatile by heat, and consequently capable of separation, in most cases, from fixed matters, so various solid bodies are subjected to similar treatment. Fluids are said to distil, solids to sublime; though sometimes both are obtained in one and the same operation. If the subliming matter converts into a solid hard mass, it is commonly called a sublimate; if into a powdery form, flowers.

The principal subjects of this operation are, volatile alkaline salts; neutral salts, composed of volatile alkali and acids, as sal ammonia; the salt of amber, and flowers of benzoin, mercurial preparations, and sulphur Bodies of themselves not volatile are frequently made to sublime by the mixture of volatile ones; thus iron is carried over by sal ammoniac in the preparation of the flores martiales, or ferrum ammoniatum.

The fumes of solid bodies in close vessels rise but a little way, and adhere to that part of the vessel where they concrete.

Super. This term is applied to several saline substances, in which there is an excess of one of its constituents beyond what is necessary to form the ordinary compound; as supersulphate of potassa, supercarbonate of soda, &c.

Trituration. The act of reducing a solid body into a subtile powder; as woods, barks, &c. It is performed mostly by the rotary motion of a pestle in metallic glass, or wedgewood mortars.

Uret. The compounds of simple inflammable bodies

with each other, and with metals, are commonly designated by this word; as *sulphuret* of phosphorus, *carburet* of iron, &c. The terms *bisulphuret*, *bisulphate*, &c., applied to compounds, imply that they contain twice the quantity of sulphur, sulphuric acid, &c. existing in the respective sulphuret, sulphate, &c.

Viscidity. Glutinous, sticky, like the bird lime.

Volatilization. The reducing into vapour, or the aeri form state, such substances as are capable of assuming it.

Way, dry. When the chemist decomposes substances by the agency of heat, he is said to operate in the *dry way.*

Way, humid. When the decomposition is produced by water or other fluids, the effect is said to be produced in the *humid way.*

APPARATUS DESCRIBED.

Acetometer. An instrument for estimating the strength of vinegars.

Adopter. A chemical vessel with two necks used to combine retorts to the cucurbits or matrasses, with retorts instead of receivers.

Æromeier. An instrument for making the necessary corrections in pneumatic experiments to ascertain the mean bulk of the gases.

Alembic. A chemical utensil made of glass, metal, or earthenware, and adapted to receive volatile products from retorts. It consists of a body to which is fitted a conical head, and out of this head descends laterally a beak to be inserted into the receiver.

Alkalometer. The name of an instrument for determining the quantity of alkali in commercial potassa and soda.

Almometer. The name of an instrument to measure the quantity of exhalation from a humid surface in a given time.

Barometer. An instrument to determine the weight of air; it is commonly called a weather-glass.

Blow-pipe. A very simple and useful instrument. That used by the anatomist is made of silver or brass, of the size of a common probe, or larger, to inflate vessels and other parts.

The chemical blow-pipe is made of brass, is of about one-eighth of an inch diameter at one end, and the other tapering to a much less size, with a very small perforation for the wind to escape. The smaller end is levelled on one side. Berzelius, in a late excellent treatise on the use of the blow-pipe in chemistry and mineralogy gives the preference to Ghan's construction, with an additional bent-beak, for a laboratory blow-pipe, and to Wollaston's for a pocket instrument.

Calorimeter. An instrument by which the whole quantity of absolute heat existing in a body in chemical union can be ascertained.

Clinometer. An instrument for measuring the dip of mineral strata.

Cryophorus. The post-bearer, or carrier of cold; an elegant instrument invented by Dr. Wollaston, to demonstrate the relation between evaporation at low temperature, and the production of cold.

Crucible. This vessel is employed in the melting of metals, and other operations of fusion. They are made, for low heats, of earthenware or porcelain, but for strong heats, of clay and sand, or clay and powdered plumbago. Hessian and Dutch crucibles, which are made of refractory clay and sand, are generally the most approved; but modern chemists have an invaluable acquisition in platina, which is often made into crucibles, and will bear, without fusion or injury, a greater heat than any other known substance.

Cupel. A shallow earthen vessel like a cup, made of phosphate of lime, which suffers the baser metals to pass through it, when exposed to heat, and retains the pure metal. This process is termed cupellation.

Cucurbits, or matrasses, are glass, earthen, or metallic

vessels, usually of an egg-shape, and open at the top. They are used for the purposes of digestion, evaporation, solution, &c.

Digester. A strong and tight iron kettle or copper furnished with a valve of safety, in which bodies may be subjected to the vapour of water, alcohol, or ether at a pressure above that of the atmosphere.

Eudiometer. An instrument by which the quantity of oxygen and nitrogen in atmospherical air can be ascertained. Several methods have been employed, all founded upon the principle of decomposing common air by means of a body which has a greater affinity for the oxygen.

Evaporating vessels. These are made of glass, wood metal, porcelain, or Wedgewood's ware. Those of the last-mentioned composition are very convenient, as they are, like glass, easily kept clean, and are not very subject to crack by changes of temperature. They are generally in the form of shallow basins, and when the matter deposited in them would be apt to burn to the bottom, and be injured, if not strictly attended to, they are placed over the fire in a vessel filled with sand, which is then called a sand-bath. When even this heat would prove too great, the heat of boiling water is used instead of sand.

Furnace. The furnaces employed in chemical operations are of three kinds: 1. The *evaporatory furnace* which has received its name from its use: it is employed to reduce substances into vapour by means of heat, in order to separate the more fixed principles from those which are more volatile.

2. The *reverberatory furnace,* which name it has received from its construction, the flame being prevented from rising. It is appropriated to distillation.

3. The *forge furnace.* In which the current of air is determined by the bellows.

Gasometer. Vessels constructed for the retention of gas, and for facilitating the drawing of it off as wanted, are called *gasometers.* They are much varied in their

construction; but those on the principle we shall now describe, are amongst the most simple, and answer perfectly well. They are a cylindrical vessel of glass, or japanned tin-plate, nearly filled with water, and having a tube in the middle open at the top, and branching at the bottom, through the side of the vessel, to which a stop-cock is attached. Within this vessel, there is another cylindrical vessel, generally of glass, open at the bottom, which is inverted, and suspended by lines which go over pullies, and have weights attached to them, which hang on the outside, to balance the inverted vessel. While the stop-cock at the bottom remains shut, if the vessel be pressed downwards, the air inclosed within it, will remain within in the same situation, on the principle of a diving bell; but if the cock be opened, and the inverted vessel be pressed down, the air inclosed within it will escape through the cock, and if a blow-pipe be attached to this cock, a stream of the gas may be thrown upon lighted charcoal, or any other body. By means of a graduated rod on the top of the inverted vessel, the quantity thrown out is exactly ascertained; this rod being so divided as to express the contents of the inner vessel in cubic feet.

Goniometer. An instrument for measuring the angles of crystals.

Hydrometer. The best method of weighing equal quantities of corrosive volatile fluids, to determine their specific gravities, appears to consist in enclosing them in a bottle with a conical stopper, in the side of which stopper a fine mark is cut with a file. The fluid being poured into the bottle, it is easy to put in the stopper because the redundant fluid escapes through the notch or mark, and may be carefully wiped off. Equal bulks of water, and other fluids, are weighed by this means to a great degree of accuracy: care being taken to keep the temperature as equal as possible, by avoiding any contact of the bottle with the hand, or otherwise. The bottle itself shows with much precision, by a rise or fall of the liquor in the notch of the stopper, whether such change has taken place.

The hydrometer of Fahrenheit consists of a hollow ball, with a counterpoise below, and a very slender stem above, terminating in a small dish. The middle, or half length of the stem, is distinguished by a fine line across. In this instrument every division of the stem is rejected, and it is immersed in all experiments, to the middle of the stem, by placing proper weights in the little dish above. Then, as the part immersed is constantly of the same magnitude, and the whole weight of the hydrometer is known, this last weight added to the weights in the dish, will be equal to the weight of the fluid displaced by the instrument, as all writers on hydrostatics prove. And accordingly, the specific gravity for the common form of tables, will be had by the proportion: as the whole weight of the hydrometer and its load, when adjusted in distilled water, is to the number 1000, &c., so is the whole weight when adjusted to any other fluid to the number expressing its specific gravity.

Hypocleptcium. A chemical vessel for separating liquors, particularly the essential oil of any vegetable, from the water; and named because it steals, as it were, the water from the oil.

Hygrometer. The state of the atmosphere, with respect to dryness or moisture, is measured by this instrument. It is sometimes called *hygroscope.*

Mortar. A sort of mould, a vessel to pound in.

Muffles. In cupellation, it is necessary for the contents of the cupel to be exposed to the access of air; the cupel must not, therefore, be used in a closed furnace, or be surrounded with fire. A kind of small ovens are therefore employed, which are called *muffles.* They are made of the same material as crucibles, and the cupel being put into them, they are exposed to the heat of the furnace. They are also used in enamelling, and other operations, where heat is required, while the contact of the fire must be taken off.

Pyrometer. As the common mercurial thermometer cannot be employed to ascertain degrees of heat above 500 or 550 degrees of Fahrenheit, it is totally inapplica-

ble to most of the operations carried on in furnaces and ovens: yet in a variety of manufactures and chemical operations, success depends upon the adjustment of the heat with a degree of nicety which the most experienced persons are incapable of determining by mere observation. To supply this desideratum, Wedgewood contrived an instrument called a *pyrometer*, the range of which extends to 32,000 degrees of Fahrenheit's scale. Its utility is derived from the property which clay has of contracting in proportion to the degree of heat to which it is exposed. This contraction is permanent, and a less degree of heat than that which the clay has experienced, will not alter its dimensions. If, therefore, a piece of clay, of a given bulk, be exposed to the heat of a furnace, it may occasionally be taken out, and upon being applied to a gauge, the degree of its contraction may be ascertained, and consequently the greatest heat to which it has been exposed, provided this gauge has been graduated by previous experiments. Wedgewood constructed this pyrometer by duly availing himself of these circumstances.

The pyrometic pieces of clay intended to be used to any given scale, should be exactly of the same composition, as different clays contract in different degrees by the same heat. To guard against the disadvantage of a difference, Wedgewood offered to the Royal Society a bed of Cornish clay, sufficiently extensive to furnish the world for ages.

The gauge for measuring the diminution which the pieces of clay suffer from the action of fire, is made of two pieces of brass, twenty-four inches long, with the sides exactly plane, divided into inches and tenths, fixed five-tenths asunder at one end, and three-tenths of an inch at the other end, upon a brass plate; and the pyrometic pieces are made at first so as just to fit the wider end. The pieces of clay are generally made about one inch long; but if their breadth be just equal to that of the wider end of the gauge, viz. five-tenths of an inch, their dimensions in other respects are not material.

It is obvious, that in proportion to the shrinking of the clay by heat, it will slide farther and farther towards the narrow end of the converging scale, one side of which is divided into tenths of an inch; and every division, of which it contains 240, answers to a 600th part of the breadth of the little piece of clay. One degree of the pyrometer is equal to 130 degrees of Fahrenheit's scale.

The regular shrinking of clay by heat, does not commence at a lower degree than a red heat fully visible in daylight; and this heat is equal to 1077½ degrees of Fahrenheit, or about 500 degrees above the point at which the mercurial thermometer terminates. It becomes therefore desirable to measure the range of temperature to which neither of these instruments applies; but nothing has yet been contrived which answers the purpose in a simple manner.

The pyrometic pieces of clay should be exposed as nearly as possible to the same heat as the material, the heat received by which they are intended to measure. For this purpose, they are usually placed close to it, and in the same crucible; but when the contents of the crucible might adhere to them, they are inclosed in a small case, made of crucible clay; and as they may be reduced in any degree, while their breadth is retained, the pyrometic piece may generally be introduced without difficulty into any but very small crucibles; and they may be disposed by the side of very small crucibles, without much hazard of receiving their heat materially sooner, or with greater intensity than the contents of the crucible.

The pyrometic piece may be taken out of the fire during any period of the process, and instantly cooled in water, so as to be ready for measuring in the gauge in the space of a few seconds. It will not crack, expand, contract, or sustain any other injury; and may be immediately replaced in the strongest fire, to resume its office of indicating higher degrees of heat than what it has already been exposed to.

The following table will give a better idea of the heats designated by the pyrometer, than any general remarks:

	Fahr.	Wedgw.
Extremity of the scale of the pyrometer	32270°	240°
Greatest heat of an air furnace, 8 inches square	21877	160
Cast-iron melts	17977	130
Greatest heat of a common smith's forge	17327	125
Welding heat of iron, greatest	13427	95
Welding heat of iron, least	12777	90
Fine gold melts	5237	32
Fine silver melts	4717	28
Swedish copper melts	4587	27
Brass melts	3807	21
Heat by which enamel colours are burnt on	1857	6
Red-heat fully visible in daylight	1077	0
Red-heat fully visible in dark	947	1
Mercury boils	600	$3\frac{673}{1000}$
Water boils	212	$6\frac{658}{1000}$
Vital-heat	97	$7\frac{542}{1000}$
Water freezes	32	$8\frac{42}{1000}$
Proof spirit freezes	0	$8\frac{280}{1000}$
The point at which mercury congeals, consequently the limit of the mercurial thermometers, about	40	$8\frac{52}{1000}$

Wedgewood found by analysis, that the clay of which his pyrometer pieces were formed, consisted of two parts of pure siliceous earth, to three parts of pure argillaceous or aluminous earth.

The use of the pyrometer shows in a remarkable manner the inaccuracy of the common mode of expressing the highest degrees of heat by estimation. Thus the heat at which copper melts is called a white heat, though it is only 27° of the pyrometer; the welding heat of iron, or 90°, is also a white heat; even 130°, and upwards, is still a white heat. These examples show very clearly

that the temperature of bodies in furnaces is raised in a manner of which we have no idea, unless the materials subjected to it are such as to give us the necessary information.

Receiver, or *recipients*. These vessels are usually glass for small operations, for receiving the volatile product from a retort or alembic; they are adapted to the neck of the before-mentioned apparatus, and secured by luting.

Retorts. These are globular vessels, formed with a long neck, and are made of earthenware, glass, or metal, according to the use for which they are designed. They are used in distillations, and most frequently for those which require a degree of heat superior to that of boiling water. The tube of a retort is usually called a beak.

Glass retorts should be very thin, and of a uniform substance in every part; otherwise, from the inequality of their expansion, they will crack with the application of a very slight heat: they cannot also be exposed to the fire, unless defended by coating, which is generally some earthy composition. Chaftal particularly recommends, for this purpose, fat earth which has been suffered to rot some hours in water; it must then be kneaded with horse dung, and formed into a soft paste, which must be equally spread over every part of the retort to be exposed to the fire. The adhesion of this coating is such, that should the retort crack during the operation, the distillation may still be carried on. The retorts used over a lamp are not coated.

Thermometer. The thermometer is a well known instrument for measuring the actual or relative temperature of bodies. Its properties are dependent upon the disposition of all bodies to acquire an equal degree of sensible heat or cold, and on the effects of heat in expanding some substances, the changes of the dimensions of which are examined by a scale of equal divisions. Mercury expands by heat, and contracts by cold, with greater uniformity than any other known fluid; it is, therefore, the most proper and the most commonly used

for thermometers, which are constructed in the following manner:

The first requisite is a glass tube, which may be obtained at the glass house, having a bulb at one end, which, together with part of the tube, is filled with purified mercury,* which, when introduced into the tube, is boiled to expel the air or moisture that might be attached to it; and at the moment it is in ebullition, the extremity of the tube, being drawn to a point by means of a blow pipe, it is hermetically sealed, to prevent any air from entering the tube. Or if the scale be graduated only to 212°, the ball is plunged into boiling water, the point to which the mercury ascends accurately marked. For the purpose of graduating the scale, the thermometer is plunged into melting ice, and the place where the mercury stands marked. From the freezing to the boiling point on Fahrenheit's scale, is 180°, or equal parts; and similar parts are taken above and below, for extending the scale.

Fahrenheit's is the one commonly used in this country, and in Great Britain. The space between the freezing

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* Mercury is generally purified by distillation; but as this operation may not be convenient to some, I shall mention Dr. Priestley's mode of purifying it, which is remarkable for its simplicity, and has an excellent effect. Let a strong 10 or 12 ounce phial, with a ground stopper, be a quarter filled with mercury to be purified; put in the stopper, hold the bottle inverted with both hands, and shake it violently, by striking the hand that supports it against the knee. After twenty or thirty strokes, take out the stopper, and blow into the phial with a pair of bellows, to change the air. If the mercury is not pure, the surface will become black in a short time; and if very foul, the black coat will appear coagulated. Invert the phial, stopping it with the finger, and let out the running mercury. Put the coagulated part into a cup by itself, and press it repeatedly with the finger, so as to get out the mercury entangled in it. Put both portions of mercury into the phial again, and repeat the process till no more black powder separates.

After the mercury has been thus purified from its admixture with baser metals, it should be boiled for about half an hour, to free it from the moisture which it is apt to contain. It may then be nearly cooled, when it is ready for the use of thermometers.

and the boiling points is divided into 180°, but the scale begins at that point of temperature which is produced by a mixture of pounded ice and muriate of ammonia, or muriate of soda, which is 32° lower, making the whole distance 212°.

The centigrade thermometer is divided into one hundred degrees, between the freezing and boiling points. The freezing point is marked 0, the boiling 100°.

In Reaumur's thermometer, the space between the freezing and boiling points is divided into eighty degrees The freezing point is marked 0, the boiling 80°.

The Russian thermometer, commonly called Delisle's, begins its graduation at the boiling point, and increases to the freezing. The boiling point is marked 0, the freezing 150°.

Other fluids, besides mercury, are sometimes used, such as linseed oil and alcohol; the latter is used particularly for measuring low degrees of temperature, where mercury would become solid.

For nice chemical experiments, an air thermometer is sometimes used. The bulb of air thermometers is filled with common air only, and its expansion or contraction is indicated by a small drop of any coloured liquor which is suspended within the tube, and moves up and down according as the air within the bulb or tube expands and contracts.

In general, air thermometers, however sensible to the change of temperature, are by no means accurate in their indications.

Remarks on Apparatus.

The list of chemical apparatus might still be farther enlarged, which are of less general application than those already noticed. It will be evident, that in a place where, as in a laboratory, several mechanical operations are usually resorted to, that a large strong table or bench is of considerable importance. Convenient small tables or blocks of wood, should also be at hand, for supporting mortars, levigating stones, an anvil, &c. A large vice, the use of which implies that of hammers, rasps, files, saws, and other implements for working wood and metals. Rods of glass, or porcelain, or even clean straws, are used for stirring mixtures in glasses and other vessels.

It is proper to have a pair of bellows; shovels, tongs, and pokers, for managing the fire, are of course necessary; and tongs of different shapes, for taking out crucibles, muffles, &c., from the furnace, which should also be at hand.

A plentiful supply of water should also be at hand, together with fuel, and many other things which it is needless to allude to. Distilled water to be used in analyses, and almost all operations which are to be conducted with exactness.

In such a place as a laboratory, where a vast variety of utensils are to be arranged, and where the eye ought to command the situation of every individual article, the arrangement should be such as to be at once commodious and easily maintained. The rule, to let every article have one place, and but one place, is very simple, and the only sure method of keeping good order.

It ought to be observed, that it is injurious to the advancement of chemical knowledge, to give currency to the idea, that no discoveries, or improvements, can be made without the aid of an extensive and costly apparatus. Every chemist should be a good mechanic, and the resources of the mechanic who attends to his pursuits with his whole will, are often sufficient to enable

him to accomplish very important ends, at little expense and by very simple means.

By these, together with a variety of other resources, which are promptly suggested to the active mind, and which will be different with persons in different situations, a demonstration of all the principal facts of chemistry may be obtained, and new experiments carried into execution, in some instances without any real expense, and in general without much.

OF SUBSTANCES.

Meaning of the term simple.

All substances in nature, when classed according to their apparent or sensible properties, may be considered either as solid, fluid, aeriform, or ethereal. But they may be distinguished by any of these characters, and yet be either simple or compound; but to make this distinguishment in the classification of substances, would be incompatible with the design of the present work; suffice it, therefore, to say in what manner chemists use the term simple. They do not mean by the term *simple*, that the body to which it is applied is absolutely known to be simple, but merely that it has never been compounded, nor is known to be capable of decomposition. Hence, a substance at this time called simple, may hereafter, by more improved modes of analysis, be proved a compound. What modern chemists call simple bodies, the ancient chemists call elements, a term which is yet sometimes used.

The combination of a substance with caloric or light, is not regarded as moving it out of the class of simple bodies, otherwise we could have nothing to denominate simple.

OF LIGHT.

The nature of light has occupied much of the attention of philosophers, and numerous opinions have been entertained concerning it. It has sometimes been considered as a distinct substance, at other times as a quality; sometimes as a cause, frequently as an effect; by some it has been considered as a compound, by others as a simple substance. Let these considerations be as they may, light has an influence upon almost all bodies which are exposed to it. It is the source of the colour of vegetables, and in a great measure, if not entirely, of their odour. Plants which grow in darkness are devoid of colour, in which case they are said to be *etiolated* or *blanched*. Gardeners avail themselves of this fact to render vegetables white and tender. Vegetables so situated that the light can only fall freely on one side of them, gradually turn to the light, and chiefly shoot out in that direction. Some whose stems are flexible, follow the course of the sun during the day, and always present the same face towards him.

The back, fins, and other parts of fish exposed to light, are coloured, but the belly, which is deprived of light, is always white.

The vegetable and animal productions of tropical countries, are distinguished by brighter colours than those of higher latitudes. The cause of this phenomenon must be referred to the greater abundance and intensity of the light, upon the action of which all colour is dependent. The superior strength of the perfumes, odoriferous fruits, and aromatic resins, of those countries, has the same origin.

All metallic oxides, but especially those of mercury, bismuth, lead, silver, and gold, become of a deeper colour by exposure to the rays of the sun; some of them become perfectly revived, others only partially. The yellow oxide of tungsten, if exposed to the light, loses weight and becomes blue. Green precipitate of iron, exposed to the solar light, also becomes blue.

Light has a considerable influence on the crystallization of salts, many of which will not crystallize without it. Camphor kept in glass bottles, exposed to the light, crystallizes in symmetrical figures on that side which is turned towards the light; and spirits of wine, water, &c., rising by insensible evaporation in half-filled vessels, constantly attach themselves to the most enlightened sides of the vessel.

It is not to be supposed that these effects are produced by the mere contact of light; on the contrary, we have abundant proofs that light has the power of entering into the composition of bodies, and of being afterwards extricated from them without any alteration. A great number of substances become luminous after having been exposed to light,—a property rendered obvious by carrying them instantly from the light to the dark: the diamond is a body of this kind; indeed, if the human hand be thrust into a strong light, through an aperture in a perfectly dark room, it will, when drawn in, and the aperture closed, be plainly seen, although the other hand is totally invisible.

Light is not homogeneous: it is composed of different coloured rays, possessing different refrangibility. The prismatic colours have been divided into seven, viz: red, orange, yellow, green, blue, indigo, and violet. Red is the least, and violet the most refrangible.

The rays of light must be extremely rare, for they cross each other in all possible directions, without the least apparent disturbance.

The solar rays have been divided into three different kinds. 1. Colorific, or those producing colour. 2. Calorific, or those producing heat. 3. Deoxydizing, expelling oxygen, and restoring the oxides of metals to their metallic state.

The different sources from which light is emitted in a visible form, are: 1. The sun and fixed stars. 2. *Combustion*, which is the act of combination of the combustible with oxygen; of course, the light emitted must have existed previously, combined with the combustible

or with oxygen. 3. Heat; when the body becomes luminous by being heated in the fire, it is said to be *red hot;* and it is found that all bodies that are capable of enduring the requisite degree of heat, without decomposition or volatilization, begin to emit light at the same temperature.

A number of terms are made use of and explained under the science of optics, which might prove instructing.

OF CALORIC.

What is denominated heat, is a sensation produced by a substance called caloric, which penetrates all bodies, diminishes the attraction of their several parts, and uniformly expands their dimensions.

By means of this powerful agent, solid metals are fused; liquids rarified; and almost all substances in nature are converted into elastic, compressible, or aeriform fluids.

It has been asserted by Levoiser, that all bodies, of whatever kind, may exist in three different states, solid, fluid, and aeriform.

Caloric is found to exist under a variety of forms or modifications. It is said to be *free* or *radiant*, and is commonly called *heat* or temperature; it is that heat which is perceptible to our senses, and affects the thermometer, whatever be its degree, or the source whence it is derived.

Combined caloric is that which does not affect the thermometer, and is not perceptible by our senses; it is retained in bodies by the force of affinity or attraction, and becomes a part of their substance.

Heat differs from caloric in this: one is the cause, the other the effect. The latter means that which produces heat; while the former is merely the sensation.

Liquids are combinations of solids with a larger portion of caloric than they naturally contain.

Instruments for measuring the relative degrees of heat, are called pyrometers, and thermometers, with suitable scales attached, indicating the degrees.

The states in which bodies exist, admit of different degrees of density or consistence, arising, for the most part, from the different degrees of caloric which they contain. Solids are of different degrees of density, from that of gold to that of jelly; liquids, from the consistence of melted glue, or melted metals, to that of ether. The different elastic fluids are susceptible of different degrees of density.

Bodies admit of different degrees of consistence without changing their state, merely through the agency of caloric.

According to late theory, caloric is composed of particles perfectly separate from each other, every one of which moves with great velocity in a certain direction. These directions vary infinitely, the result of which is, that there are rays or lines of these particles, moving with immense velocity, in every possible direction. Caloric, then, is universally diffused, so that when any portion of space happens to be in the neighbourhood of another, which contains more caloric, the colder portion receives a portion of the calorific rays from the latter sufficient to restore an equilibrium of temperature. This radiation not only takes place in free space, but extends also to bodies of every kind. Thus you may suppose that every body whatsoever, is continually sending forth rays, when the body is surrounded with an elastic medium. or in a vacuum.

These rays are capable of reflection and refraction.

The manner in which bodies are affected by rays producing heat, differs in different substances, and is very much connected with their colours.

Bodies that absorb the most light and of course radiate heat, are heated the most when exposed to solar or terrestrial rays.

Black bodies in general are more heated than red, red more than green, green more than yellow, yellow more than white.

All bodies are, in a greater or less degree, conductors of caloric.

Bodies with respect to caloric are divided into two kinds, good and bad conductors.

Metals and liquids are good conductors of caloric, but silk, cotton, wool, wood, feathers, &c., are bad conductors.

A short rod of iron put into the fire at one end, will very soon become hot at the other end; but a piece of wood or cane of the same length, placed precisely in the same circumstances, may be burnt to ashes at one end, without producing scarcely a sensation of warmth at the other.

The facility with which bodies are cooled or heated, is in proportion to their conducting power.

Good conductors both give and receive caloric quicker, and in a given time more abundantly, than bad conductors, which is the cause of their feeling hotter or colder; though they may be in fact of the same temperature, as indicated by the thermometer.

In general, the most dense bodies are the best conductors of heat; probably, because the denser the body, the more the number of points that come into contact with caloric.

Deep lakes are not frozen in winter. This is owing to the circumstance of cold air being constantly presented to the surface of the lake, which causes a portion of water to lose its temperature, and thus becoming heavier, falls gradually to the bottom, while the warmer water from below ascends, forming a new surface in its place.

Caloric dissolves water and converts it into steam, by insinuating itself between the particles which are so minutely divided as to become invisible.

When vapour of boiling water first issues from the vessel, it is invisible, because it is then completely dissolved by caloric. But when it comes in contact with the cold air, it is condensed, in consequence of a part of the caloric being imparted to the air. The particles of water being in a great measure deprived of their solvent, gradually collect, and became visible in the form of steam, and when further deprived of caloric, return to their liquid state.

The atmosphere dissolves water by means of the caloric which it contains. This is called *evaporation*, and differs from *vaporization*, which is caused by culinary heat.

The earth being a great radiator of caloric, parts with its heat more readily than air. When the solar heat declines and entirely ceases in the evening, the earth rapidly cools by radiating heat towards the skies; whilst the air has no means of parting with its heat, but by coming in contact with the cool surface of the earth, to which it communicates its caloric. The solvent power being thus reduced, the water is deposited in small drops called dew.

OF OXYGEN

Oxygen is the name given to the solid particles of oxygen gas, which is a combination of oxygen, caloric, and light, and is the simplest form in which oxygen can be obtained. Oxygen is called the radical or base of the gas; and the same mode of expression is used in other cases.

Oxygen gas was discovered by Dr. Priestley, on the 1st of August, 1774. It is invisible, perfectly elastic like common air, and possesses neither taste nor smell. It is 740 times lighter than water. Its weight to atmospheric air, is as 1103 to 1000.

Oxygen has never been procured in an uncombined state. Its greatest purity is that of gas. It is not made solid by any degree of cold, and therefore differs in this respect from vapours which may be condensed into a liquid, and converted into a solid.

Oxygen enters into chemical combination with a great number of substances, in which it exists in a concrete or solid state; it is by the application of heat, or of acids, to some of the substances containing it, that it is usually procured in the form of gas.

Oxygen gas may be obtained with the greatest facility and purity, from hyper-oxymuriate of potass. A small retort must be partly filled with this salt, and exposed

to the heat of a lamp; the salt melts, and oxygen is extricated in abundance, as it is held by this singular substance in a state of great concentration, and by a very weak affinity.

Ingenhouz obtained from four ounces of nitrate of potass, melted with a little slacked lime, 3000 cubic inches of this gas. Let any quantity of this salt be put into an earthern or iron retort, to the extremity of which is adapted a bent tube, terminating in the pneumatic trough. The retort must be gradually made red-hot, when the oxygen gas will be rapidly disengaged, and will be very pure.

When considerable quantities of oxygen are required, the black oxide of manganese is most frequently used, as it is the cheapest article that can be employed, and supplies the gas in a good degree of purity. The manganese is put into a retort, which is made red-hot, and the gas is collected by the pneumatic apparatus, as in using nitrate of potass. One pound of the best manganese will yield upwards of 1400 cubic inches of the gas. The retort is easily cleared of the manganese when the experiment is ended; and if the manganese that has once been used, be exposed to the air for some time, it will serve again; but the cheapness of the article renders this of little consequence.

Red oxide of mercury, and of lead, yield oxygen in the same manner as manganese.

Oxygen gas is the only one that can be breathed by animals for any length of time with impunity. The power of atmospheric air in supporting respiration, is owing to the oxygen.

In respiration, a quantity of atmospheric air is taken into the lungs; the oxygen disappears, and a quantity of carbonic acid gas, equal in bulk, is formed in its stead. A reciprocal influence is exerted between this aerial fluid and the circulating blood; and the continuance of life is dependent upon the due exercise of this influence, which appears by the conversion of oxygen into carbonic acid.

Animals confined in oxygen gas will live four or five times longer than when confined in atmospheric air.

It may be breathed by men for some time, without producing any other effect than a sensation of warmth and slight stricture of the chest.

Oxygen forms about 22 *per cent.* of the atmospheric air: the rest is nitrogen or azotic gas, except a smal quantity of carbonic acid.

Oxygen combines with all the metals; and in that state, they are called metallic oxides, depriving them of their metallic lustre, and giving them an earthy or rusty appearance.

Some of the metals become oxidized, or are rusted by mere exposure to the damp atmosphere.

Iron, exposed to the weather, soon becomes rusty, by attracting oxygen from the air or water.

All oxides are heavier than the metal, in proportion to the quantity of oxygen with which they are combined.

Many of the metals are capable of combining with different proportions of oxygen. Those with one proportion are called *protoxides;* of two, *deutoxides;* those of three, *tritoxides.*

A metal combined with the greatest proportions of oxygen is called *peroxide.*

Oxygen has a powerful effect on vegetable colours, producing the various tints of shade which we behold in this department of nature.

Yarn, when taken from the blue vat, is green, but, on exposure to the air, it imbibes oxygen, and is changed to a blue.

It is well known to the dyers, that they cannot produce a good black without exposing their stuffs to the air.

Vegetable colours fade on exposure to the sun, which is probably owing to this principle: the oxygen which previously existed in the colouring matter in a solid form, is renderedaeriform by the rays of the sun, and is evolved in the form of gas.

OF NITROGEN.

Nitrogen is the basis of the nitric acid. It exhibits itself in its simplest state as a gas. It was formerly called azote, because it was destructive to animal life.

Nitrogen gas is most easily described by including many of its negative qualities. It has no taste; it neither reddens vegetable blue colours, nor precipitates lime-water; it is not absorbed by water. It unites to oxygen in several proportions; it also unites to hydrogen. Though incapable of being breathed above its base, nitrogen is a component portion of all animal substances. It is lighter than oxygen. Dr. Black found that a vessel of 1000 cubical inches, which will contain 315 troy grains of atmospheric air, will contain 335 of oxygen gas, but only 297 of nitrogen gas.

Nitrogen gas may be variously obtained. If the oxygen be extracted from the atmospheric air, this substance will remain, and will generally be very pure, unless the oxygen has been extracted by respiration. If iron filings and sulphur, moistened with water, be put into a jar containing atmospherical air, this gas will, in a day or two, be all the air that remains in the jar, as the oxygen will be absorbed by the iron and sulphur. Phosphorus, or sulphuret of lime or potass, inclosed with common air in a jar, will produce a similar effect.

Nitrogen gas may likewise be obtained from animal substances. For this purpose, put some small pieces of lean muscular flesh into a retort, and cover them with weak nitric acid. The heat of a lamp will extricate the gas, which may be collected by the pneumatic apparatus.

It has been conjectured that nitrogen is not a simple substance, but no experiments have decisively proved this.

Atmospherical air contains 78 parts in the 100, by measure of nitrogen gas; the 22 remaining parts, or oxygen, being thus largely diluted, becomes proportionately less intense in its stimulating effects, and fit for the purposes of life, the length of which is increased by this

source of moderation in its course. By mixing pure nitrogen gas and oxygen gas in the proportions just mentioned, a gas having all the properties of atmospherical air is the result.

Though animal life cannot be sustained for a moment by nitrogen gas, yet it is congenial to vegetables, and appears to be a part of their food; they derive it from its combinations with oxygen in atmospherical air.

OF HYDROGEN.

The third and last substance, which, in its simplest form, can only be obtained in an aerial state, is called *hydrogen*. This gas has long been generally known by the name of *inflammable air;* it is the gas which miners call *fire damp*.

Hydrogen with oxygen forms water; and it is by the decomposition of water that chemists obtain it in the greatest abundance and purity. For this purpose, iron filings or turnings, or granulated zinc, are put into a retort, and covered with sulphuric acid diluted with four times its weight of water. A violent effervescence ensues, a large quantity of gas is evolved, and issuing from the retort, is collected in the usual manner by the pneumatic apparatus. In this experiment, the acid is not decomposed; it is the oxygen of the water with which the acid is diluted, that seizes upon and oxidizes the metal, and the hydrogen in the same portion of water being then disengaged, passes over in the state of gas. The hydrogen obtained by using zinc is the purest; that obtained by using iron generally containing some carbon.

The process just described is the readiest for obtaining this gas, but it is evolved in every instance in which metals are tarnished or rusted by moisture, and it may be obtained in great quantities, by causing the vapour of water to pass through an iron tube, or through a tube of any kind, containing a coil of iron wire, heated to ignition. The operation is generally conducted by the

use of a furnace, provided with small holes opposite each other, to admit the tube to pass through it.

Hydrogen, like oxygen and nitrogen, is invisible, elastic, and inodorous; but the last quality it seldom possesses, because it is very seldom perfectly dry, and when it contains water in solution, like alkaline sulphurets, its odour is considerably fetid. It generally contains half its weight of water, and when it is received over water, its volume is one-eighth larger than when received over mercury.

Hydrogen gas is the lightest of all substances, except light and caloric. When pure, it is nearly 13 times lighter than common air. It is this extreme levity which occasions its utility for inflating balloons.

Hydrogen gas is incapable of supporting life, but may be inhaled and exhaled a few moments without fatal effects; it is returned by the lungs unaltered, and does not therefore appear to be positively noxious, but only operates by excluding oxygen.

Although so currently called inflammable air, hydrogen gas is not capable of being burned, or of supporting combustion, unless oxygen be present.

That water is in reality the union of oxygen and hydrogen, is proved not only by these gases being obtained by its decomposition, but by reversing the experiment and producing water from the gases themselves. Fifteen parts, by weight, of hydrogen, being mixed with 85 parts of oxygen, and retained in a close vessel, if the hydrogen be fired by the electric spark, the gases will be converted into water, the weight of which will be equal to both the gases employed, and the gases disappear.

The oil and resin of vegetables are derived from the decomposition of water; and composts are partly beneficial as manures, from the hydrogen furnished in the process of putrefaction: if the compost be kept till this putrefaction is nearly over, its value is materially lessened as the hydrogen flies off.

Hydrogen combines with a larger quantity of oxygen than any other body; its combustion. therefore when

mixed with oxygen, produces a more intense heat than any other combustion. This may be shown with a bladder filled with oxygen, and another with hydrogen, by causing a stream from each bladder to pass through a tube upon a piece of ignited charcoal, or any other burning combustible. Each of the bladders should be furnished with a stop-cock, and as there is some risk of a violent explosion, bladders may be used with more propriety than any other vessels.

Hydrogen is capable of combining with sulphur, phosphorus, carbon, and arsenic; and these compounds are respectively distinguished by the terms sulphuretted hydrogen, phosphuretted hydrogen, carburetted hydrogen, and arseniated hydrogen. The flame which it yields in combustion is differently tinged, according to the substance combined with it. Fireworks have been constructed, in which the diversity of colour in the flame was produced by an attention to this property.

Pit-coal, by distillation, affords carburetted hydrogen, which is employed in what are called the gas lights. The coal thus distilled is not lost, but is converted into coke, which is as valuable as the coal from which it was produced.

Sulphuretted hydrogen has an offensive smell, resembling rotten eggs. It is produced by dissolving the sulphurets in acids: that disengaged by the sulphuric acid burns with a blue flame; that produced by the nitric acid burns with a yellowish white flame; the latter acid disengages the largest quantity of the gas.

Phosphuretted hydrogen, which has also a strong fetid, putrid smell, may be obtained by boiling in a retort a little phosphorus with a solution of potass. If this gas comes in contact with the air as it escapes from the retort, it takes fire, and a dense conical wreath of smoke arises from it. It explodes if suddenly mixed with oxygen, oxymuriatic acid, or nitrous oxide gas. The ignis fatuus, or jack-with-a-lantern, is attributed to this disengagement of the gas from the putrid effluvia common in swampy places where that phenomenon is observed.

Arseniated hydrogen may be obtained by adding sulphuric acid, diluted with twice its weight of water, to four parts of granulated zinc and one of arsenic. Two parts of this gas, with one of oxygen, will explode loudly, and the products are water and arsenious acid.

OF SULPHUR.

Sulphur, or brimstone, is a well-known substance, of a yellow colour, brittle, moderately hard, devoid of smell, but not entirely so of taste. Its specific gravity is 1990. It is a non-conductor of electricity, and therefore becomes electric by friction.

Sulphur is extremely disseminated, and is obtained abundantly, both in a state of purity, and from its combinations with other substances. It flows from volcanoes, and is sublimed from the earth in some parts of Italy. It is combined more or less frequently with most ores, and is procured in large quantities from some of them, particularly those of iron and copper. In the Isle of Anglesea, it is sublimed from the copper ore, and collected in large chambers, which are connected with the kilns by means of horizontal flues.

Sulphur unites with most of the metals, rendering them brittle, and increasing their fusibility. It is soluble in oils, and by heat in alcohol, but water has no immediate action upon it. Hydrogen gas dissolves it, and is then called sulphuretted hydrogen. This gas is evolved during the putrefaction of animal substances. Sulphur unites with phosphorus by heat; but with charcoal it does not combine.

If a bar of iron or steel, at a white heat, be rubbed with a roll of sulphur, the two bodies combine and drop down together in a fluid state, forming sulphuret of iron, a compound of the same kind as the native sulphuret of iron called pyrites, and which, from its abundance, supplies much sulphur.

If potass or soda be melted by a moderate heat, with equal parts of sulphur, in a covered crucible, it forms a

substance, which, after cooling, is of a liver-brown colour. These compounds are respectively called the sulphuret of potass or soda.

Orpiment, or king's yellow, is a sulphuret; it is composed of arsenic and sulphur Vermilion is the red sulphuret of mercury.

Sulphur sublimes at the heat of 170°, and is collected in the form of what is called *flowers of sulphur.* If heated to 185°, it becomes very fluid, but by a continuance of the heat its fluidity diminishes, and it even becomes thick; on being allowed to cool, its former fluidity returns before it becomes solid. If as soon as the sulphur has begun to congeal, the inner liquid part be poured out, the internal cavity will exhibit long needle-shaped crystals of an octahedral figure.

Sulphur combines with oxygen in four definite proportions, forming an interesting class of acids, viz: the *sulphurous, hypo-sulphurous, sulphuric, and hypo-sulphuric.* From these combinations it is inferred that its prime equivalent is 2, and the density of its vapour is 1.111, equal to that of oxygen.

Sulphur is applied to many important uses. It is employed in medicine, it enters into the composition of sulphuric acid, of gunpowder, and of the common composition for paying the bottom of ships. Its fumes are employed in bleaching silk and wool, and checking the progress of vinous fermentation. Common matches, for lighting fires, are tipped with sulphur.

OF CARBON.

Vegetables, when burnt or distilled in close vessels, till their volatile parts are entirely separated, leave a black, brittle, and cinerous residuum, which constitutes the greater part of the woody fibre, and is called *charcoal.* Charcoal contains a portion of earthy and saline matters, but when entirely freed from these and other impurities, a solid, simple, combustible substance remains, which is called *carbon.*

Carbon exists naturally in a state of greater purity than it can be prepared by art. The diamond is pure carbon crystallized. The diamond, when pure, is colourless and transparent. It is the hardest substance known; and, as it sustains a considerable degree of heat unchanged, it was formerly supposed to be incombustible. It may, however, be consumed by a burning-glass, and even by the heat of a furnace. The difficulty of burning it appears to arise from its hardness; for Morveau and Tennant have rendered common charcoal so hard by exposing it for some time to a violent fire in close vessels, that it endured a red heat without catching fire. Common charcoal contains only 64 parts of diamond, or pure carbon, and 36 of oxygen in every 100.

The common charcoal of commerce is usually prepared from young wood, which is piled up near the place where it is cut, in conical heaps, covered with earth, and burnt with the least possible access of air. When the fire is supposed to have penetrated to the centre of the thickest pieces, it is extinguished by entirely closing the vents. When charcoal is wanted very pure, the product of this mode of preparing it will not suffice; for the manufacturing of the best gunpowder, it is distilled in iron cylinders. Chemists prepare it in small quantities, in a crucible covered with sand; and, after they have thus prepared it they pound it, and wash away the salts it contains by muriatic acid; the acid is removed by the plentiful use of water, and afterwards, the charcoal is exposed to a low red heat. Pure charcoal is perfectly tasteless, and insoluble in water.

Charcoal, newly prepared, absorbs moisture with avidity. It also absorbs oxygen, and other gases which are condensed in its pores, in quantity many times exceeding its own bulk, and are given out unaltered Fresh charcoal, allowed to cool without exposure to air, and the gas then admitted, will absorb 2.25 times its bulk of atmospheric air immediately, and .75 more in four or five hours; of oxygen gas, about 1.8 immediately, and slowly, 1 more; of nitrogen gas, 1.65 immediately;

of nitric oxide, 8.5 very slowly; of hydrogen gas, about 1.9 immediately; carbonic acid gas, 14.3 immediately. The greater part of these gases are expelled by a heat below 212°, and a portion even by immersing the charcoal in water. These absorptions are promoted by a low temperature; but, at an elevated temperature, charcoal has such an affinity for oxygen, that it will abstract it from almost all its combinations. Hence, its utility in reviving metals.

Fossil coal, and all kinds of bitumen, contain a large quantity of carbon: it is also contained in oils, resins, sugar, and animal substances.

Charcoal is one of the most unchangeable substances; if the access of air be prevented, the most intense heats have no other effect than that just mentioned of hardening it, and rendering its colour a deeper black. Insoluable in water, and incapable of putrefaction, it undergoes no change by mere exposure or age; and stakes, and other materials of wood which have been charred, or superficially converted into charcoal, have been preserved from decay for thousands of years; the ancients availed themselves of this mode of preparing stakes which were to be driven into the ground for foundations and other purposes.

The combinations of carbon with various substances, are called carburets. Steel is a combination of iron and carbon, in which the proportion of carbon is very small, only about a two hundredth part; it is to its carbon that it owes its valuable property of admitting to be tempered. Cast-iron contains more carbon than steel, but this difference is not the only cause of the difference of the properties of iron in the two states; from its carbon, however, cast-iron admits of being made hard or soft, nearly in the same manner as steel. Plumbago contains 90 parts of carbon, and but ten of iron; it is from this excess of carbon, called a *hyper-carburet of iron*. The name of black lead, by which it is most generally known, is evidently improper, as it contains not a particle of lead. On the contrary, the connexion of plumbago with

iron might be inferred from its resemblance in some respects to that kind of cast-iron which contains most carbon; their fracture is much alike; and very fine filings of the iron tinge the hands nearly in the same manner as the powdered plumbago. Yet cast-iron seldom contains more than a forty-fifth part of its weight of carbon.

Charcoal possesses the singular property of combining with, and destroying the odour, colour, and taste, of various substances. Putrid and stinking water may be rendered sweet by filtering it through charcoal-powder, or even by agitation with it. Common vinegar boiled with charcoal-powder, becomes perfectly limpid. Saline solutions that are tinged yellow or brown, are rendered colourless in the same way, so that they will afford white crystals. Malt spirit may be freed from its disagreeable flavour by distillation with about $\frac{1}{160}$ of its weight of charcoal. Tainted vessels, after having been well scoured, may have every remaining taint removed by rinsing them with charcoal-powder; and this powder will also restore the sweetness of flesh-meat but slightly tainted with putridity. As a dentrifice, charcoal in the state of an impalpable powder, is unrivalled, at once whitening the sound teeth, and sweetening the breath by neutralizing the fetor that arises from those which are carious, or from a scorbutic state of the gums.

When charcoal is burnt in oxygen gas, nearly the whole of it disappears: it is converted by its combinations with oxygen into an aeriform fluid, which, having the properties of an acid, is called *carbonic acid gas*. It contains 28 parts, by weight, of charcoal, and 72 of oxygen in every 100. It was discovered by Dr. Black, in 1755, and the discovery constitutes a memorable epoch in the history of chemistry, as it was attended with so clear a demonstration of the fact, that gaseous substances could become concrete, or form a part of solid substances, and that, on the contrary, solid substances could assume the gaseous form.

Carbonic acid gas is nearly twice as heavy as atmo

spheric air, and it may therefore be poured from one vessel to another, or retained in a cask and drawn off like other liquors. Though invisible, yet if contained in a glass, the presence of something different from common air may be discovered by lighting a piece of paper, and putting it into a glass; the light will instantly go out, and the smoke becoming entangled in this heavy gas, will show the quantity of the gas that may be present. The extinction of fire by this gas is instant and complete; and when by any accident it is breathed, it prevents the power of speech, and rapidly destroys life. As it is evolved in the process of fermentation, it is often present in vats, and the public journals frequently record instances of persons who have incautiously descended into these vessels to clean them, perishing from its bane ful effects in a few moments.

Carbonic acid gas is always the result of the combustion of charcoal, which cannot be burnt in a close apartment, without imminent hazard of suffocation to the persons present. This gas is often contained in deep old wells, and places which have been long closed; wherever it is suspected to exist, it will be proper to introduce a lighted candle, and if that burns as usual, no danger need be apprehended; but if it be extinguished, it may be taken for granted that the air is unfit to breathe. A quantity of water, particularly if mixed with quick-lime, will, if thrown into a suspected place, absorb the carbonic acid which may be present. Carbonic acid gas constitutes what miners call *choke-damp*.

Carbonic acid, though so deleterious when breathed, often forms a palatable wholesome ingredient in food, as it possesses the strongly antiseptic properties of carbon, its base. Hence the acid taste of Pyrmont, Spa, and other mineral waters; hence the sparkling and agreeable briskness of fermented liquors, such as beer, cider, &c. Yeast, from the large quantity it contains of it, has performed wonderful cures in putrid diseases. The atmosphere contains a very small quantity of this gas, the use of which may be to neutralize the putrid miasmata con-

tinually flying about. Water may by pressure be caused to combine with nearly three times its own bulk of carbonic acid gas.

The combinations of carbonic acid with other substances, are called *carbonates*. Common chalk, lime-stone, and marbles, are all carbonates, and in their chemical composition differ but little from each other. Carbonic acid gas may be obtained from any of these, by putting them into a retort in powder, and pouring upon them a diluted acid, for example the sulphuric. The gas must be collected by the pneumatic apparatus. A cubical inch of marble contains as much carbonic acid, as, in the state of gas, would fill a vessel of six gallons.

OF PHOSPHORUS.

Phosphorus is a yellowish, transparent substance, of the consistence of wax. It is luminous in the dark at common temperatures, and at 67° it emits a white smoke. It is rapidly consumed at 122°. It is preserved by keeping it in water: the water has, however, the effect of rendering it opaque; and even exposure to light alters it in some degree.

Phosphorus was originally prepared from urine, by a tedious and disagreeable process; but Gahn, a Swedish chemist, having discovered that it existed in bones, it is now prepared from this class of bodies. The bones are calcined till they cease to smoke, after which they are reduced to a fine powder. This powder is put into a glass vessel, and sulphuric acid is gradually poured upon it, till the further addition of acid occasions no extrication of air bubbles. This mixture is largely diluted with water, well agitated, and kept hot for some hours; it is then filtered, and afterwards evaporated slowly, till a quantity of white powder falls to the bottom. This powder, by a second filteration, is separated, and thrown away. The evaporation is then resumed; and whenever any white powder appears, the filteration must be repeated, in order to separate it. During the whole pro-

cess, what remains on the filter must be washed with pure water, and this water added to the liquor. The evaporation is continued till all the moisture disappears, and nothing but a dry mass remains. This mass is put into a crucible, and kept melted in the fire, till it ceases to yield a sulphurous smell; it is then poured out. When cold, it resembles a brittle glass: it is pounded in a glass mortar, and mixed with one-third, by weight, of charcoal dust. This mixture is put into an earthenware retort, to which is adapted a receiver, containing a little water. In a short time after the retort and its contents have become red-hot, the phosphorus passes into the receiver, drop by drop. It is generally formed into small cylinders, by moulding it under lukewarm water, in glass tubes, or by putting a cork into the extremity of the pipe of a glass funnel, into which hot water may then be poured, and the phosphorus being dropt in, will mould itself. From the remark made above, respecting the low temperature at which it burns, it is necessary to take great care that none of it adheres to the hand, especially under the nails, whence it would be with difficulty extracted; as the heat of the body would kindle it, and it burns with extreme ardour. If, however, it be thoroughly mixed with several times its bulk of hog's lard, it may be held in the hand without injury.

Phosphorus possesses a prodigious divisibility. A quarter of a grain being administered in some pills to a person who was afterwards opened, all the internal parts were found to be luminous, and even the hands of the person who opened the body had the same appearance.

Phosphorus combines with oxygen, hydrogen, nitrogen, sulphur, most of the metals, and some of the earths. By combining with oxygen, that is, after combustion, it forms phosphoric acid. When the phosphoric acid is combined with any substance, that substance is called a *phosphate*. The phosphorus in bones is in a state of phosphate of lime. The combination of phosphorus with iron forms that kind of iron called *cold-short*, which is brittle when cold, though malleable when heated.

Phosphorus, rubbed in a mortar with iron filings, takes fire immediately. Phosphoric match-bottles are prepared by mixing one part of flour of sulphur with eight of phosphorus. If a very small quantity of this mixture be taken out on the point of a match, and rubbed upon a cork, or any similar body, the match becomes lighted.

At the temperature of 70° F., phosphorus combines with oil, and forms a compound, which, in contact with atmospheric air, becomes luminous in the dark.

Put one part of phosphorus into six parts of good olive oil, or oil of cinnamon, which is preferable. Digest it in a gentle sand heat, until the phosphorus is dissolved, on which, immediately cork the bottle. If this oil be rubbed on any thing, it immediately becomes luminous in the dark, and yet has not sufficient heat to burn the substance.

OF WATER.

The composition of water has already been incidentally mentioned; it consists of 85 parts of oxygen, and 15 of hydrogen. It is a product of combustion, being formed whenever hydrogen is united to oxygen; for these two bodies are not known to be capable of uniting in any proportion but that which forms water. The proofs of the composition of water are complete; this fluid may be decomposed, that is, separated into the gases of which it is composed; or the gases may be converted into water.

Water is capable of existing in four different states, 1. that of ice; 2. that of water, or the liquid state; 3. that of steam, or the gaseous state; 4. in combination with crystals or other solids.

1. Ice is the simplest state of water; if entirely deprived of caloric, it would still be ice, only increasing in hardness as the caloric was abstracted. It is elastic, and when long kept much below the point at which it is formed, it becomes extremely hard. When pulverized, it is white. As one of the amusements of the court of Russia, in the severe winter of 1740, a palace was constructed entirely of ice hewn from the river Neva; and

a cannon made of the same material, drove a hempen bullet through a board two inches thick at the distance of sixty paces. Water expands in passing to the state of ice, with a force that produces most astonishing effects; rending trees, and separating immense fragments, from the rocks and mountains. This expansion is owing to the new arrangement of its particles; the needles of the crystals crossing each other, either at angles of 60 or 120°. Ice is converted into water when its temperature is raised above 32°.

2. Water retains its character as a fluid, at all temperatures between 32° and 212°. It is employed as the standard of comparison in all tables of specific gravities.

Water, when perfectly pure, possesses a high degree of transparency, and is entirely destitute of colour, taste, and smell. It is nearly inelastic, and consequently incompressible. It can only be obtained pure by distillation; for as it is capable of holding a greater number of substances in solution than any other fluid, the facility with which it becomes impregnated with foreign substances must be obvious.

3. When water is converted into vapour, it combines with above five times the quantity of caloric which would be required to bring ice-cold water to the boiling heat; it is estimated to fill a space 1800 times greater than in the state of water; and the large quantity of caloric with which it is combined, is the only cause of the difference. This refers to water under the common pressure of the atmosphere. When this pressure is lessened, as under an exhausted receiver, water assumes the state of vapour at a very gentle heat; and when retained in a sufficiently strong vessel, as in Papin's digester, it may be rendered red-hot without being converted into steam. The elasticity of steam is prodigious; and it increases with the heat at which the steam is formed. It has been found by experiments, that the expansive force of steam exceeds that of gunpowder.

4. The singular tenacity with which water is held by a great number of substances, is an interesting fact.

Saussure has proved that alumine will retain one-tenth of its weight of water, at a heat which will keep iron in fusion; lime retains water with nearly the same force; and calcined plaster of Paris is changed from a state of powder to that of a solid, by combining with a large portion of water; some salts, though tolerably hard and dry, are combined with as much water, as at a boiling heat would hold them in solution; crystals owe their transparency, and even their solidity, to the water combined with them, for they lose both these properties as soon as the water is abstracted. By entering into many of these combinations, it is evident that water is deprived of a greater quantity of caloric than in a state of ice, and it is to this cause that we must attribute its hardness in gems.

MINERAL WATERS.

The purest water which nature affords is melted snow, or of rain newly fallen, and collected in open fields, at a distance from houses, or contaminated atmosphere. The water of rivers and lakes is next in purity, especially where it is a rocky or gravelly bed. Stagnant water, and that of marshes, is in general exceedingly impure, and often offensive to the taste, as it is largely impregnated with principles derived from the putrefaction of animal and vegetable matters. All these waters, however, possess the property called *softness;* that is, they will dissolve soap. Spring waters are generally hard: they will not dissolve soap; and are, therefore, unfit for any domestic purposes, and for manufacturers. This arises from their containing earths and minerals in solution. Springs which supply water of a more agreeable taste than rain, river, or lake water, are the most abundant; and they always contain carbonic acid. Other impregnations impair their taste; and, when they are in such access as to give a marked character to the water, the waters of such springs are called *Mineral waters.*

It may often be important to obtain a general idea of

the impregnations of a particular spring, in order to know whether it can be safely taken with food, or is likely to be useful as a medicine, or ought to be wholly rejected. We shall therefore give a short account of the tests, by which the most usual impregnations may be detected.

The sensible qualities of water, such as transparency, colour, taste, and smell, should be examined, if possible, at the instant it comes from the spring. If the water must necessarily be examined at a distance, a bottle, with an air-tight stopper, should, at the fountain-head, be completely filled with it, in order to leave no space for air. The specific gravity should also be taken. To note exactly the sensible qualities of the water, will often indicate the re-agents which may be employed to denote its composition.

Spring water generally contains more or less carbonic acid, which imparts an agreeable sparkling and briskness; like that exhibited by fermented liquors. Where no colouring matter is present, the sparkling induces us to suppose this water more transparent than other waters.

Carbonic acid sinks the taste of every other ingredient in waters; and, therefore, such waters should not only be tasted at the spring, but some time after they have been exposed to the air, or after they have been boiled, as the carbonic acid will then have escaped. The tincture of litmus will discover whether an acid is present in water, and as the carbonic is the only acid which is separated by exposure to the air, this exposure, if it deprive the water of the power of reddening litmus-paper or its solution, will show whether the acid is the carbonic or not.

Water containing carbonic acid will hold a considerable quantity of carbonate of lime in solution. Lime is detected most effectually by oxalic acid, which separates it from all its combinations, and forms with it an insoluble precipitate, unless an excess of acid be present, for then the precipitate will be re-dissolved. It is, therefore best to use the oxalate of ammonia or potass, in order that the alkali may neutralize the acid in solution.

Diluted muriate of barytes will form a precipitate with water containing sulphuric acid. The precipitate is white, and insoluble in diluted muriatic acid.

The nitrate of silver occasions a white precipitate or cloud in water containing muriatic acid.

Alkalies held in solution, or alkaline or earthy carbonates, change paper stained with turmeric to a brown, or reddish brown, and light vegetable reds are rendered blue. The volatile alkali may be distinguished by its smell. Earthy and metallic carbonates are precipitated by boiling.

Iron is very common in mineral waters; it may be detected by its forming a purple or blackish precipitate with tincture of galls, or blue with prussiate of potass.

Pure ammonia, or lime-water, precipitates magnesia and alumine, and no other earths, provided the carbonic acid has previously been separated by a fixed alkali and boiling.

The mineral acids, when uncombined, give a permanent red to litmus paper, both before and after the water has been boiled; whereas, the redness communicated by the carbonic acid gas goes off as the paper dries.

Waters containing the sulphate of copper, may be detected by their giving the colour of copper to a polished plate of iron immersed in them.

Sulphate of iron is precipitated by alcohol.

The specific gravity of sea-water is generally 1.0289. It holds about $\frac{1}{70}$ of its weight of muriate of soda in solution, with a small quantity of muriate of magnesia, and a still smaller proportion of the sulphate of lime. At a distance from land, it is colourless and void of smell, but intensely saline and bitter.

In analyzing waters with exactness, the gaseous products they afford are carefully collected and examined.

OF THE AIR.

The atmosphere may be said in general terms to consist of oxygen and nitrogen; but atmospheric air, even

when purest, always contains a small proportion of other principles. Murray states its exact composition as follows

	By measure.	By weight.
Nitrogen gas	77.5	75.55
Oxygen gas	21.0	23.32
Aqueous vapour	1.42	1.03
Carbonic acid gas	.08	.10
	100.0	100.0

As considerable quantities of hydrogen escape from the earth, it might be presumed that it would be found in the atmospheric air, but as the atmospheric air has no chemical attraction for it in any proportion that can be detected, it probably escapes, by its levity, beyond the heights to which we have access. Dalton's experiments evince that the proportion of carbonic acid gas does not exceed a thousandth part, though a higher estimate is generally made.

Atmospheric air is destitute of taste and smell, highly compressible, and perfectly elastic. It supports animal life, directly by the oxygen it affords to the lungs, where the blood combines chemically with it; and indirectly, by its mechanical properties in equalizing the temperature of the globe, and preventing too rapid an evaporation of the moisture of the body. It is also not less necessary to vegetable life, as the vehicle for the distribution of water, and in its decompositions, by furnishing them with nitrogen, carbonic acid, and other principles.

Atmospheric air contains the only proportion of oxygen which is subservient to the purposes of existence: all the known gases have been tried. None of them except the nitric oxide, can be breathed for even a few moments; and even the nitric oxide, during the short time which it remains on the lungs, produces a suspension of the proper functions of the mind. In all the gases, also, combustion is either intemperate or wholly stopped. Notwithstanding the multiplied compositions and decompositions which are continually going on at

the surface of the earth, the due proportion of oxygen in the air is still maintained with a precision truly astonishing.

The specific gravity of the air is less, the greater the proportion of aqueous moisture which it contains. Hence, aeronauts find that their balloon sinks when passing over the sea, where the air is moister than over the land.

OF GAS.

This term is applied to all permanently elastic fluids, simple or compound, except the atmosphere, to which the term *air* is appropriated.

Some of the gases exist in nature without the aid of art, and may, therefore, be collected; others, on the contrary, are only producible by artificial means.

All gases are combinations of certain substances, reduced to the gaseous form by the addition of caloric. It is, therefore, necessary to distinguish, in every gas, the matter of heat which acted the part of a solvent, and the substance which forms the basis of the gases.

Gases are not contained in those substances from which we obtain them in a state of gas, but owe their formation to the expansive property of caloric.

The formation of gases.—The different forms under which bodies appear, depend upon a certain quantity of caloric, chemically combined with them. The very formation of gases corroborates this truth. The production totally depends upon the combinations of the particular substances with caloric; and though called permanently elastic, they are only so because we cannot so far reduce their temperature, as to dispose them to part with it; otherwise they would undoubtedly become fluid or solid.

Water, for instance, is a solid substance in all degrees below 32° of Fahrenheit's scale; above this temperature it combines with caloric, and it becomes a fluid. It retains its liquid state under the ordinary pressure of the atmosphere, till its temperature is augmented to 212°. It then combines with a larger portion of caloric, and is

converted, *apparently*, into gas, or at least into elastic vapour; in which state it would continue, if the temperature of our atmosphere was above 212°. Gases are therefore solid substances, between the particles of which a repulsion is established by the quantity of caloric.

But as in the gaseous water or steam, the caloric is retained but with little force, on account of its quitting the water when the vapour is merely exposed to a lower temperature, we do not admit steam among the class of gases, or permanently elastic aeriform fluids. In gases, caloric is united by a very forcible affinity, and no diminution of temperature, or increase of pressure, that has ever yet been effected, can separate it from them. Thus the air of our atmosphere, in the most intense cold, or when very strongly compressed, still remains in the aeriform state; and hence is derived the essential characters of gases, namely, *that they shall remain aeriform, under all variations of pressure and temperature.*

OF ALCOHOL.

Alcohol, or the purely spiritous part of liquors which have undergone the vinous fermentation, and no other, is transparent and colourless like water; its taste is highly pungent, but agreeable. It is extremely inflammable, and when set on fire it leaves no residuum. Its specific gravity is 0.800; and from its brightness and extreme fluidity, the bubbles which are formed on its surface, break with rapidity. It is not frozen even by the extreme cold of 65°; but it has been frozen by the sudden abstraction of its caloric in the vacuum of an air-pump. In a vacuum, it boils at 56°; in the air it is converted into vapour at 55°, and boils at 165°. It is from its being converted into vapour much sooner than water, that it is easily separated by distillation from wine, beer, and other liquors which contain it. All these liquors owe their strength to the quantity of alcohol they contain: the best port-wine contains about one-fourth of its bulk of alcohol. Brandy, rum, and whiskey, contain still more alcohol. Proof-spirit is half water and half alcohol.

The alcohol obtained by distillation always contains some water, from which that operation will not free it; to obtain pure alcohol, therefore, perfectly dry potass, obtained by exposing this alkali for some time to a red heat, is put into it: the water, having a stronger affinity for the potass than for the alcohol, combines with the alkali, which falls to the bottom, and the alcohol may be drawn off with the siphon. Afterwards the alcohol should be distilled with a gentle heat, and not quite to dryness, that any potass it may contain may be left behind.

Alcohol mixes with water in all proportions, and the combination is so intimate that the mixture takes up less space than the fluids separately; and therefore, as in every other combination where such an effect happens, caloric is extricated, and may be felt by the hand.

Alcohol is the grand solvent for resins, and is much used for making varnishes. Camphor dissolves in it very readily, and the solution hastens that of some substances upon which the alcohol alone acts but slowly, or not at all, particularly copal.

Alcohol takes up a small portion of phosphorus, which is precipitated by water. Quicklime alters the flavour of alcohol, and renders its colour yellow, though the earth in general, and metallic oxides, appear to have no action upon it. Both fixed and essential oils are soluble in alcohol.

The composition of alcohol is not accurately known. The analysis of Lavoisier indicated that 100 parts of it contain of carbon, 30, of hydrogen, 7.5, and of water 62.5: but the accuracy of the analysis is doubtful; for, as it was conducted by burning the alcohol in oxygen, part of the water may have been the produce of combustion, as Fourcroy and Vauquelin have clearly proved that alcohol contains oxygen. However this be, the manner in which the component parts of alcohol are united, remains entirely a mystery.

Betancourt has ascertained the important fact, that the vapour of alcohol has more than double the expansive force of that of water of the same temperature, and

that the steam of alcohol, at 174°, is equal to that of water at 212°. Hence, it has been suggested that alcohol may be employed with advantage as the moving power of steam engines, with a great saving of fuel, and consequently, of expense, when means shall be contrived to save the fluid from being lost.

OF ETHER.

If alcohol be mixed with its own weight of sulphuric acid, gradually added, to prevent explosion, and the mixture be distilled in a sand bath, the first product obtained is alcohol, but afterwards a very different fluid, which is equal in quantity to half the alcohol employed. This fluid is called *ether*.

Ether is still more inflammable and volatile than alcohol, and equally as colourless. It is the lightest of all known fluids. Its smell is fragrant and agreeable, but not powerful. Its taste is hot and pungent. Its combustion yields a blue flame, and rather more smoke than alcohol. It boils at 98°. It may be obtained of the specific gravity of .716.

It is a valuable medicine; being used externally for the headache or toothache, by pouring a little upon the hand and pressing it upon the forehead or cheek, till the pain it occasions goes off. Its internal use extends to all spasmodic affections.

The nature of the change produced on alcohol by the acid, when ether is formed, is not well understood; but it is supposed that ether contains a much larger proportion of hydrogen in proportion to its carbon.

If the distillation of ether be continued till sulphurous vapours appear, and the recipient be then changed, a new product is obtained; it is called the *sweet oil of wine*, which is unctuous, thick, less volatile than ether, and of a yellow colour. The last product obtained by urging the fire, is sulphuric acid and acetous acid.

Instead of the sulphuric acid, ether may be prepared with the nitric, the oxymuriatic, the acetic, and several

other acids. According to the acid employed, its properties differ a little: nitric ether is often made, but the sulphuric is the most common and the most valued. The peculiar properties of the ethers made with different acids, have not been minutely examined.

Sulphuric ether acts upon most resinous substances; it is the best solvent of caoutchouc; it dissolves also the essential oils and camphor; mixes in all proportions with alcohol, but water only dissolves a tenth of it. It combines with caustic volatile alkali; but not with the fixed alkalies or lime. It dissolves a little sulphur and phosphorus.

If the ether obtained emit a sulphurous odour, it must be purified by a second distillation, previous to which it should be mixed with a little potass, which will combine with the acid, and in part with the water.

OF METALS.

The metals, from their extensive and diversified utility, are amongst the most interesting classes of substances existing. They are supposed to be simple bodies, and not a single fact has ever been ascertained which shows that they can be converted into each other; yet, to accomplish this, the alchemists exhausted their estates and their lives.

The metals are distinguished by their possessing all or the greater part of the following properties; hardness, tenacity, lustre, opacity, fusibility, malleability, and ductility; and they are excellent conductors of caloric, electricity, and galvanism.

Metals are generally found in mountainous countries. They are sometimes met with in a state of purity, and are then said to be found native: but they are mostly combined with other substances; and, when combined in such quantities as to be worth separating, the substance is called an ore of the metal it contains.

All the metals are susceptible of crystallization. The easiest mode of obtaining their crystalline form, is to let

out the middle part just after they have begun to congeal; the interior of the crust thus left assumes a crystalline form.

The metals are fusible at very different temperatures; mercury, for example, does not become solid, unless cooled down to 39°, and platina is not softened at the heat at which cast-iron runs like water.

Metals differ from each other as much in hardness as in fusibility. Kirwan has adopted a very simple mode of showing their comparative hardness by figures. We shall adopt his plan, which he thus explains:

3. Denotes the hardness of chalk.

4. A superior hardness; but yet what yields to the nail.

5. What will not yield to the nail; but easily, and without grittiness, to the knife.

6. That which yields with more difficulty to the knife.

7. That which scarcely yields to the knife.

8. That which cannot be scraped by a knife, but does not give fire with steel.

9. That which gives a few feeble sparks with steel.

10. That which gives plentiful, lively sparks.

Great specific gravity was formerly considered as one of the chief characteristics of the metals, the lightest metal being twice as heavy as the heaviest body of any other sort; but the discovery of several bodies, which possess all the characters of the metals, excepting weight, and which cannot therefore be omitted in the list of metals, has caused great specific gravity to be no longer distinctive.

If a metal be exposed to a heat which will keep it in fusion, it may, without suffering any alteration but that of its figure, (which will adapt itself to the vessel,) be kept any length of time in that state, provided the access of air be kept entirely from its surface. But if the fusion be conducted in open vessels, the surface of the metal loses its metallic brilliancy; and if its apparent scum be removed, another is soon formed, until the whole of the metal disappears, and instead of it we have an earthy

opaque powder which soils the hands. Upon collecting and weighing this powder, it is found to be heavier than the metal from which it was produced. This process was by the ancient chemists called *calcination*, and the product of it was called a *calx;* they knew not the cause of it, and were, therefore, wholly unable to account for the increase of weight which they obtained by it; but the moderns having thoroughly investigated the subject, consider all metals as combustible bodies; that in the operation just described the metal has suffered combustion, and that, therefore, the oxygen of the atmosphere has combined with it, as it combines with all other bodies during combustion, and that it is solely from the oxygen absorbed that its additional weight is derived. In proof of this, they find by suitable experiments, that the oxygen absorbed is exactly equal to the weight acquired; and also, that when the oxygen is taken away, by presenting some substance for which it has a greater affinity, the metal acquires all its original properties, and becomes of the same weight as at first. Hence for the vague term calx, the modern chemists used the word *oxide*, to denote the earth-like combinations of a metal with oxygen; and the act or process in which this change takes place, is called *oxidation*.

Oxygen will not combine with metals in all proportions, as acids will do with water, but only in one or two, or at most a few proportions. When the proportion of oxygen varies, the oxide of the same metal assumes different colours; the colour is therefore selected to distinguish these differences. Hence, we have the *yellow oxide of lead*, *the red oxide of lead*, &c. When the oxygen which converts a metal into an oxide is supplied by an acid, the name of the solvent, as well as the colour of the oxide, is sometimes given: thus we have the *white oxide of lead by the acetous acid.*

Some of the metals are so much disposed to oxidation, that they became oxides at all temperatures. Iron is a metal of this description: the rust to which it changes in air or water is its red oxide.

If the oxide of a metal be exposed to a strong heat, it vitrifies, or is converted into a substance resembling common glass. The substances employed for enamel painting, for colouring glass, and for glazing earthenware, are mostly prepared from metallic oxides.

If any of the malleable metals be hammered, its combined caloric becoming sensible, renders it hot, and passes off to surrounding bodies; the metal at the same time is rendered denser, harder, more rigid, and in general more elastic. A portion of the caloric, to which, in common with other bodies, metals owe their softness, appears to be driven out of it; for its former state returns by heating it to ignition. Rolling produces the same effect as hammering.

The metals combine with each other, and besides oxygen, with the simple substances, sulphur, carbon, and phosphorus. When two metals are combined together, the mixture is called an *alloy* of that metal whose weight predominates.

Previous to the year 1730, only eleven metals were known, the list is now increased to forty-two chiefly by recent discoveries, andthe probability is very strong, that there exists a much larger number. The metals may be divided into two classes;—the malleable and the brittle; the brittle metals may be further subdivided into those which are easily fused, and those which are fused with difficulty. We shall enumerate them, in each of these classes, in the order of their specific gravity.

1. *Malleable Metals.*

1. Platina,
2. Gold,
3. Mercury,
4. Lead,
5. Palladium,
6. Silver,
7. Nickel,
8. Copper,
9. Iron,
10. Tin,
11. Zinc,
12. Sodium,
13. Potassium.

2. *Brittle Metals, fused without difficulty.*

1. Bismuth,
2. Arsenic,
3 Antimony,
4. Tellurium.

Brittle Metals, of difficult fusion.

1. Tungsten,
2. Uranium,
3. Rhodium,
4. Cobalt,
5. Molybdenum,
6. Manganese,
7. Tantalium,
8. Titanium,
9. Chromium,
10. Columbium,
11. Cerium,
12. Osmium,
13. Iridium

PLATINA.

The specific gravity of platina, after hammering, is 23,000. It, therefore, holds the pre-eminence of all bodies in point of weight, and it has other extraordinary properties.

It is incapable of tarnishing by exposure to the air The strongest mineral acids have no effect upon it, if employed separately, nor will the strongest fire melt it, unless urged by oxygen gas; a crucible of it not thicker than a sheet of paper, will endure the heat of the best furnace, and come out unaltered. When intensely heated, it possesses, like iron, the property of welding, but the labour of working it is very great. Its hardness is 7.5. Its colour is between that of iron and silver.

Platina was unknown in Europe before the year 1741, when a quantity of it was brought by Charles Wood, from Jamaica. It was supposed only to be found in the gold mines in Peru, but Vauquelin has met with it in Spain, in the mines of Guadalcanal. Its name, in the language of Peru, signifies *little silver*, and on its great specific gravity being ascertained, attempts have been made to prevent its use, lest gold should be adulterated with it. It has never been met with except in the metallic state, in the form of smooth grains of all sizes up to that of a pea, but very seldom larger.

Platina may be fused by a powerful burning-glass; but its total infusibility by ordinary means, has caused various processes to be resorted to, for obtaining it in a solid, malleable state. For this purpose it must be dissol

ved in an acid; oxymuriatic acid, and nitromuriatic acid both dissolve it. The latter acid should consist of one part of nitric, and three of muriatic acid. The solution is very corrosive, and tinges animal substances of a blackish brown colour; it affords crystals by evaporation. Count Moussin Pouschin directs malleable platina to be prepared from its solution as follows: Precipitate the platina by adding a solution of muriate of ammonia, and wash the precipitate with a little cold water. It is red-coloured, which distinguishes this metal from gold. Reduce it in a convenient crucible to the well-known spongy metallic texture, wash the mass obtained two or three times in boiling water, to carry off any portion of saline matter that may have escaped the action of the fire. Boil it in a glass vessel for about half an hour, in as much water mixed with one-tenth of muriatic acid, as will cover it about half an inch. This will carry off the iron that might exist in the metal. Decant the acid water, and edulcorate or strongly ignite the platina. To one part of this metal take two parts of mercury, and amalgamate in a glass or porphyry mortar. This amalgamation takes place very readily. The proper method of conducting it, is to take about two drachms of mercury to three of platina, and amalgamate them together, and to this amalgam may be added alternate small quantities of platina and mercury, till the whole of the two metals is combined. Several pounds may thus be amalgamated in a few hours, and in the large way, a mill might shorten the operation. As soon as the amalgam of mercury is made, compress it in tubes of wood, by the pressure of an iron screw upon a cylinder of wood adapted to the bore of the tube. This forces the superabundant mercury from the amalgam, and renders it solid. After two or three hours, burn upon the coals, or in a crucible lined with charcoal, the sheath, in which the amalgam is contained, and urge the fire to a white heat; after which the platina may be taken out in a very solid state, fit to be forged.

The ductility of platina is such, that it has been drawn

into wire of less than the two-thousandth part of an inch in diameter. This wire admits of being flattened, and is stronger than that of gold or silver, of the same thickness.

Platina will not combine with gold, except in a violent heat. When not more than one forty-seventh of the alloy is platina, the gold is not perceptibly altered in colour; but, if the proportion be materially greater, the paleness of the gold betrays its impurity. Added in the proportion of one-twelfth to gold, it forms a yellowish-white metal, highly ductile, and so elastic, that Hatchett supposed it might be used for watch-springs, and other purposes. Its specific gravity was 19.013.

It also requires a violent heat to make platina and silver combine; the silver becomes less white and ductile, but harder. If the two metals be kept for some time in fusion, they separate, and the platina, from its greater weight, sinks to the bottom.

The alloy of copper and platina is hard, yet ductile, while the copper is in proportion of three or four parts to one. This alloy is not liable to tarnish, especially when the platina predominates; and it is, therefore, excellent for the specula of reflecting telescopes, as platina takes an excellent polish, and reflects a single image. The addition of a little arsenic improves this alloy. But copper is much improved in colour, grain, and susceptibility of polish, when the platina is only in proportion of a tenth or fifteenth.

Alloys of platina with tin or lead are very apt to tarnish; that with lead is formed at the strongest heat: it is not ductile, and the lead is not absorbed by the cupel, unless it is in excess; and even then, the separation of the lead is not complete.

Platina unites easily with tin; the alloy is very fusible, but its grain is coarse and brittle. It is ductile, when the proportion of tin is large: it becomes yellow by exposure to the air.

Zinc renders platina more fusible, and forms with it a very hard alloy The zinc cannot be entirely separated by heat.

Bismuth and antimony likewise facilitate the fusion of platina, with which they form brittle alloys, and are not wholly separated by heat. Arsenic has the same effect as these metals in promoting its fusion.

Platina has not been united to forged iron; but with cast iron, it forms an alloy which resists the file.

If phosphorus be thrown upon red-hot platina, the metal is fused, and forms a phosphuret, which is of a silvery white, very brittle, and hard enough to strike fire with steel. As heat expels the phosphorus, Pollitier proposed this as an easy method of purifying platina; but he afterwards found that the last portions of phosphorus were retained by too strong an affinity.

Several of the metallic salts decompose the solution of muriate of platina. Muriate of tin is so delicate a test of it, that a single drop, recently prepared, gives a bright red colour to muriate of platina, which before this addition, is so clear as to be scarcely distinguished from water.

If nitro-muriatic solution of platina be precipitated by lime, and the precipitate digested in sulphuric acid, a sulphate of platina will be formed. A sub-nitrate may be formed in the same way.

Platina does not form a direct combination with sulphur, but is soluble by the alkaline sulphurets, and precipitated from its nitro-muriatic solution by sulphuretted hydrogen.

The fixedness of platina admirably fits it for crucibles, and many other chemical utensils, which may be made thinner of this than of any other material whatever. It is, however, besides the disadvantages of its expense, liable to corrosion from caustic alkalies, and some of the neutral salts.

If either be mixed and agitated with the nitro-muriatic solution of platina, it takes up the metal; and, as it will soon float on the surface of the solution, it may be poured off, and, if brushed over the clean surface of any other metal, it will soon evaporate, and impart to them a coating of platina.

GOLD.

Gold is the most malleable, ductile, and most brilliant of all the metallic substances; and, next to platina, the heaviest and most indestructible.

Gold is seldom found except in the metallic state. It has been obtained in every quarter, and almost every country of the globe; but South America supplies a greater quantity than all the rest of the world.

Many laborious experiments have been repeatedly made by able chemists, who appear to have established the fact, that gold exists in vegetables.

A single grain of gold can be made to cover an area of more than 400 square inches; a wire of one-tenth of an inch in diameter will support a weight of 500 pounds; and Dr. Black has calculated that it would take fourteen millions of films of gold, such as cover some fine gilt wire, to make up the thickness of an inch; whereas the same number of leaves of common writing paper would make up nearly three quarters of a mile.

Though opacity is enumerated as one of the characters of the metals, yet gold, when the $\frac{1}{282000}$th of an inch thick, which is about the thickness of ordinary gold leaf, transmits light of a lively bluish green colour. Perhaps all the other metals, if they could be equally extended, would show some degree of transparency, but none of them can be made so thin.

The specific gravity of unhammered gold, is 19.258, and is increased but little by hammering. Its hardness is 6. It melts at 32°, of Wedgwood; and if pure, its colour when in fusion is not yellow, but a beautiful bluish green, like the light which it transmits.

Gold cannot be volatilized, except at an extreme heat. The utmost power of Parker's celebrated burning lens, exerted upon it for some hours, did not cause it to lose any weight which could be discovered; but Lavoisier found that a piece of silver, held over gold melted by a fire maintained with oxygen gas, was sensibly gilt: and perhaps the same delicate test would have shown its volatility by the lens.

After fusion, gold will assume the crystalline form. Tillet and Mongez obtained it in short quadrangular pyramidal crystals.

Gold unites with most of the metals. Silver renders it pale; when the proportion of silver is about one-fifth part, the alloy has a greenish hue. Silver separates from gold as from platina, if the alloy be kept for some time in fusion.

Gold is strongly disposed to unite with mercury; this alloy forms an amalgam, the softness of which is in proportion to the quantity of mercury. It is by mercury, that in South America, gold is chiefly obtained from the earth with which it is mixed, and the gold is separated by distillation. This alloy readily crystallizes after fusion. It is applied by gilders to the surface of clean copper, and the mercury is driven off by heat.

Gold unites freely with tin and lead, but both these metals impair its ductility. Of lead, one quarter of a grain to the ounce renders the gold brittle; but tin has not so remarkable an effect.

Copper increases the fusibility of gold, as well as its hardness, and deepens its colour. It forms the usual addition to gold for coin, plate, &c. The standard gold of Great Britain is twenty-two parts pure gold, and two parts copper; it is, therefore, called "gold of twenty-two carats fire."

Iron forms an alloy with gold, so hard as to be fit for edge tools. Its colour is grey, and it obeys the magnet.

Arsenic, bismuth, nickel, manganese, zinc, and antimony, render gold white and brittle. When the alloy is with zinc in equal proportions, it has a fine grain, takes a high polish, and from these qualities, and its being not liable to tarnish, it forms a composition not unsuitable for the mirrors of telescopes.

For the purpose of coin, Hatchett considers an alloy consisting of equal parts of silver and copper as the best, and copper alone as preferable to silver. The same distinguished chemist gives the following order of different metals, arranged as they diminish the ductility of gold:

viz. Bismuth, lead, antimony, arsenic, zinc, cobalt, manganese, nickel, tin, iron, platina, copper, silver. The first three were nearly equal in effect, but the platina was not quite pure.

The nitric acid will take up a very minute quantity of gold, but the nitro-muriatic and oxy-muriatic acids are its only real solvents. The two latter acids are of a similar nature, and their effects on gold are increased by concentrating them, by enlarging the surface of the gold and by the application of heat. The solution is of a yellow colour, caustic, and tinges the skin of a deep purple. By evaporation it affords yellow crystals, which take the form of truncated octahedrons. These crystals are a muriate of gold; they may be dissolved in water, and will stain the skin in the same manner as the acid.

Most metallic substances precipitate gold from its solution in the nitromuriatic acid: lead, iron, and silver, precipitate it of a deep and dull purple colour; copper and iron throw it down in its metallic state; bismuth, zinc, and mercury, likewise precipitate it. When precipitated by tin, it forms the *purple precipitate of Cassius*, which is much used by enamellers and manufacturers of porcelain.

Ether, naphtha, and essential oils, take gold from its solvent, and from liquors which have been called potable gold, and are used in gilding. The gold obtained from these fluids by evaporation, is extremely pure.

If diluted nitromuriatic solution of gold be used to write with upon any substance, and the letters while yet moist, be afterwards exposed to a stream of hydrogen gas, the gold will be revived, and the substance will appear gilt. Ribbons may be gilt in this manner. Sulphurous acid gas revives the gold in the same manner.

Lime and magnesia precipitate gold from its solution in the form of a yellowish powder. Alkalies do the same, but an excess of alkali re-dissolves the precipitate. The precipitate obtained by means of a fixed alkali appears to be a true oxide; it is taken up by the sulphuric, nitric, and muriatic acids, but separates by standing with crys-

tallizing. The precipitate by gallic acid is of a reddish colour, and very soluble in the nitric acid, to which it communicates a blue colour.

Gold precipitated from its yellow solution by ammoniac, forms a powder called *fulminating gold;* this dangerous compound detonates by friction, or a very gentle heat. It cannot be prepared or preserved without great risk. Macquer gives an instance of a person who lost both eyes by the bursting of a bottle containing some of it; and which exploded by the friction of the glass-stopper against an unobserved grain of it in the neck of the bottle.

Green sulphate of iron precipitates gold of a brown colour; but this soon changes to the colour of gold.

The alkaline sulphurets precipitate gold from its solution; the alkali unites with the acid, and the gold falls down combined with the sulphur. The sulphur may be expelled by heat.

The alkaline sulphurets will also dissolve gold. Thus, if equal parts of sulphur and potass, with one-eighth of their joint weight of gold in leaves, be fused together, the mixture, when poured out and pulverized, will dissolve in hot water, to which it gives a yellowish green hue. Stahl wrote a dissertation to prove that Moses dissolved the golden calf in this manner.

Sulphur alone has no effect on gold. The process called dry-parting is founded upon this circumstance. This is used for separating a small quantity of gold from a large quantity of silver. The alloy is fused, and flowers of sulphur are thrown upon its surface; the sulphur reduces the greater part of the silver to a black scoria. The small remainder of the silver may now be separated by solution in nitric acid. The advantage of the operation consists in saving the large quantity of nitric acid which would have been required to dissolve the silver of the alloy in its original state.

The heat produced by the electro-galvanic discharge reduces gold to the state of a purple oxide.

MERCURY.

Mercury is distinguished from all other metals, by its fluidity at the common temperature of the atmosphere. Its colour is white, and its surface is like that of polished silver. Its specific gravity is 13.580; and it is, therefore, the heaviest of all substances, except platina and gold.

Mercury boils at 655; and does not cease to be a fluid, unless at or below the temperature of —39°. In Russia, and Hudson's Bay, this temperature sometimes occurs naturally; it may, however, be obtained by a freezing mixture. Mercury has then been examined, and found to be perfectly malleable, working like soft tin. Experiments with artificial cold afford but few opportunities for exhibiting this property; but at Hudson's Bay, where surrounding objects were all equally cold, frozen mercury has been beaten upon an anvil into sheets as thin as paper. A mass of it, being thrown into a glass of warm water, became fluid, but the water was immediately frozen, and the glass shivered to pieces. To the touch, frozen mercury excites the same sensation as red-hot iron.

Mercury is frequently obtained from the mines in the pure metallic state; sometimes it is combined with silver, but mostly with sulphur, in combination with which it is called *cinnabar*, when the mixture is of a red colour, but Ethiop's mineral, when it is black. These are both sulphurets of mercury. Mercury is supplied by many countries. The mines of Idria, in the circle of lower Austria, have been wrought for 300 years, and are estimated to yield 100 tons annually. From Spain, which supplies large quantities, it is exported to South America for amalgamating with gold; for which use, the consumption is so prodigious, that the mine of Guanca Velica, in Peru, does not supply enough. This mine is a vast cavern, 170 fathoms in circumference, and 480 fathoms deep.

Cinnabar, to obtain the metal from it, is mixed with

quick-lime, and then submitted to heat. The lime combines with the sulphur, and the mercury which sublimes from the mixture is collected in receivers. Mercury sublimes at the heat of 600°, and then has the appearance of a white smoke. In this state of vapour, its elasticity renders it capable of bursting the strongest vessels, if the attempt be made to resist its expansion. Distillation is the ordinary means of purifying mercury.

Mercury combines very freely with gold, silver, lead, tin, bismuth, and zinc; not so freely with copper, arsenic, and antimony; for iron, its affinity is extremely slight, and less so still, if possible, for platina.

The alloy of mercury with any metal, if the mercury predominates so far as to render it soft, and of the consistence of butter, is called an *amalgam*. These amalgams are much employed in silvering and gilding, as the mercury is easily driven off by heat, and the fixed metal is left behind. The metal with which the backs of looking-glasses are coated, is an amalgam of tin and mercury.

The number of metals with which mercury combines, renders it extremely liable to adulteration. The union is in some cases so strong, that the baser metal will rise along with it in distillation. The experienced eye can, however, determine very small adulterations, by the want of perfect fluidity and brightness. Impure mercury also soils white paper, and the presence of lead may be detected by agitating the metal with water, by which means it will be oxidized. Or a very minute quantity of lead, present in a large quantity of mercury, may be detected by solution in nitric acid, and the addition of sulphuretted water. A dark brown precipitate will ensue, and will subside in the course of a few days. One part of lead may be thus separated from 15,263 parts of mercury. Bismuth is detected by pouring a nitric solution, prepared without heat, into distilled water; this metal will be separated in the form of a white precipitate. If tin be present, a weak solution of muriate of gold will cause a purple precipitate.

By agitating mercury for some time in oxygen or atmospheric air, a part of it is converted into a black oxide.

Most of the acids have more or less action on mercury. The sulphuric acid requires the assistance of heat, and sulphurous acid gas is disengaged during its action, and a white oxide is formed, which becomes yellow by pouring hot water upon it, and is then called *turbith mineral;* it is a subsulphate of mercury; the water holds in solution sulphate of mercury.

The nitric acid dissolves mercury rapidly without heat; nitrous gas is disengaged, and the colour of the acid at the same time becomes green. If the acid be strong, it will take up its own weight of mercury in the cold, and will bear dilution; heat will enable the acid to dissolve much more of the metal, and the addition of distilled water will form a precipitate, which is yellow if the water be hot, and white if it be cold. This, from its resemblance to the turbith mineral mentioned above, is called *nitrous turbith.*

All the combinations of mercury with nitric acid are strongly caustic, and form a deep black or purple spot on the skin. When nitrate of mercury is exposed to a gradual and long continued low heat, it gives out a portion of nitric acid, and is converted into a bright red oxide; this oxide retains a small portion of nitric acid; it is called *red precipitate*, which is employed in medicine as a caustic. This red oxide parts with its oxygen simply by heat, and the mercury recovers its metallic state. The finest precipitate is made, by distilling the mercurial solution till no more vapour arises; then adding several successive portions of acid, and distilling it dry after each addition. The precipitate will thus be obtained in small crystals of a superb red colour. Red precipitate may be prepared by heat only: the mercury must for this purpose be kept at the heat of about 600° for several months; the red oxide thus formed was called *precipitate per se.*

The acids, the alkalies, the earths, and most of the

metals, precipitate mercury from its solution in the nitric acid. The precipitates by alkalies have the property of exploding, if triturated with one-sixth of their weight of flowers of sulphur, and afterwards gradually heated.

The muriatic acid does not act on mercury, except by long digestion, which enables it to oxidize a part, and it dissolves the oxide. This acid, however, completely dissolves the mercurial oxides, which, when nearly in the metallic state, or containing but little oxygen, form the muriate of mercury. When the oxy-muriatic acid is employed, the *oxy-muriate* of mercury, or *corrosive sublimate*, is formed. Corrosive sublimate is highly caustic and poisonous.

Sulphur readily combines with mercury. If triturated with this metal in a mortar, it forms with it a black sulphuret, formerly called *ethiop's mineral*. This compound may also be formed by adding to sulphur in fusion one fourth of its weight of mercury.

If ethiops mineral, or black sulphuret of mercury, be sublimed, it affords the red sulphuretted oxide, or artificial cinnabar. This cinnabar, when pounded and washed for painters' use, is called *vermilion*. To prepare it with accuracy, let 300 grains of mercury and 68 of sulphur, with a few drops of solution of potass to moisten them, be triturated in a porcelain mortar, with a glass pestle, till converted to the state of black oxide. Add to this 160 grains of potass, dissolved in as much water. Heat the vessel containing the ingredients over the flame of a candle, and continue the trituration without interruption during the heating. In proportion as the liquid evaporates, add clear water from time to time, so that the oxide may be constantly covered to the depth of near an inch. The trituration must be continued about two hours; at the end of which time the mixture begins to change from its original black colour to a brown, which usually happens when a large part of the fluid is evaporated. It then passes very rapidly to a red. No more water is then to be added, but the trituration is to be continued without interruption. When the mass has acquired

the consistence of a jelly, the red colour increases in brightness with surprising rapidity. The instant the colour has acquired its utmost beauty, the heat must be withdrawn, otherwise the red passes to a dirty brown. This is Kirchoff's method of preparing vermilion. Count Moussin Pouschin discovered that the brown colour may be prevented by taking the sulphuret from the fire as soon as it begins to be red, and placing it in a gentle heat, taking care to add a few drops of water, and to agitate the mixture from time to time. By this treatment an excellent red is obtained.

Phosphorus, mixed with red oxide of mercury, and distilled, forms a *phosphuret of mercury*, which is of a black colour, and in the air exhales phosphoric vapours.

PALLADIUM.

Palladium is of a greyish white colour, scarcely distinguishable from platina, and takes a good polish. It is ductile, and very malleable; flexible, when reduced to thin slips, but not very elastic. Its fracture is fibrous, and in diverging striæ, showing a kind of crystalline arrangement. It is harder than wrought iron. Its specific gravity is about 10.9, but may be increased by hammering and rolling to 11.8. It is a less perfect conductor of caloric than the other metals, and less expansible, though in this respect it exceeds platina.

Palladium was discovered by Dr. Wollaston in native platina. When exposed to a strong heat, its surface tarnishes a little, and becomes blue; but by increasing the heat, it becomes bright. By an intense heat, it is fused, but not oxidized. Its oxides, formed by means of acids, may be reduced by heat alone.

Palladium may be obtained by adding to nitro-muriatic solution of crude platina, a solution of prussiate of mercury, on which a flaky precipitate will gradually be formed, of a yellowish white colour. This is prussiate of palladium, from which the acid may be expelled by heat.

The sulphuric, the nitric, and the muriatic acids dissolve a small portion of palladium, and acquire by it a red colour. The nitro-muriatic dissolves it rapidly, and acquires a deep red.

Alkalies and earths precipitate palladium from its solutions, generally of a fine orange colour; an excess of alkali partly re-dissolves the precipitate.

Alkalies act upon metallic palladium; and this action is assisted by the contact of air.

Green sulphate of iron precipitates palladium in a metallic state; and all the metals, except gold, silver, and platina, do the same. Prussiate of mercury produces a yellowish white precipitate; and, as it does not precipitate platina, it is an excellent test of palladium.

Palladium forms with gold a grey alloy, harder than gold, less ductile than platina, and of a coarse-grained fracture.

With an equal weight of platina, it resembles platina in colour and hardness; but it is not so malleable, and melts at a heat a little higher than is requisite to fuse the palladium. The specific gravity of this alloy is 15.141.

With an equal weight of silver, the alloy is harder than silver, but softer than wrought-iron, and its polished surface resembles platina, except that it is rather whiter; specific gravity 1.29.

Equal parts of palladium and copper, are a little more yellow, break more readily, assume somewhat of a leaden hue when filed, and are harder than wrought iron. Specific gravity 10.392.

Lead increases the fusibility of palladium, and forms with it an alloy of a grey colour, fine-grained fracture, harder than any of the preceding alloys, but very brittle

With tin, bismuth, iron, and arsenic, palladium forms brittle alloys: that with bismuth is very hard.

LEAD.

The colour of lead is a bluish white; its specific gravity is 11.352; its hardness is 5; it is the softest, the least elastic and sonorous, of all metals used in the arts. It melts before ignition. It has scarcely any taste, but friction causes it to emit a peculiar smell. It stains paper and the fingers of a bluish black.

Lead is very malleable, and therefore easily reduced to thin plates by the hammer; but hammering neither increases its specific gravity or hardness. Its ductility is not great; a wire one-tenth of an inch in diameter, will support only 29¼ pounds.

It is not certainly known that lead has ever been found in the metallic state; the only lead ore that is extensively found and worked, is a sulphuret of lead; it is called *galena*, and is generally found in veins, both in siliceous and calcareous rocks. Lead ore frequently contains silver, and often antimony and bismuth.

To obtain lead from galena, the galena is pulverized, and separated by washing from earthy admixtures; it is then roasted in a reverberating furnace, and afterwards melted in contact with charcoal. When the lead contains a quantity of silver worth extracting, it is fused in a strong fire, and the wind from a pair of bellows being directed over its surface, the whole of it is in succession converted into a yellow scaly substance called litharge, which being driven off as it forms, the silver is left at the bottom of the crucible. The litharge is a sub-carbonate of lead, and by fusing it with charcoal the lead is revived.

When lead is fused in an open vessel, its surface quickly loses its lustre, and a scum appears, which is soon converted into a darkish grey powder. In the heat usually employed to melt lead, this grey powder or oxide sustains no further alteration; but, if spread upon a suitable surface, and exposed to a low red heat, it becomes successively whitish, yellow, and lastly, of a bright orange red. The yellow oxide is called by painters *masticot;* the red they call *minium*, or merely *red lead*

If the heat be urged much further, red lead is converted into litharge, which is a semi-vitreous substance; that, by a little further heat, becomes a complete yellow glass, of so fusible a nature, as to penetrate and destroy the best crucibles. This glass enters into the composition of flint-glass. It promotes its fusibility, renders it heavier than other glass, better capable of bearing sudden changes of temperature, and from its greater softness, more suitable for cutting and polishing.

When lead is exposed to the atmosphere, the brightness of its surface gradually diminishes, till it is nearly of the same colour as the grey oxide produced by heat. This oxide forms an even but a very superficial covering, and it defends the metal from any further change.

Most of the acids have an action on lead; but for this purpose the sulphuric acid must be concentrated and boiling. Sulphurous acid gas escapes during the solution, and the acid is decomposed. By distilling the solution to dryness, a sulphate of lead is obtained: it is of a white colour, and affords crystals. This sulphate is caustic, and may be decomposed by lime and the alkalies.

The nitric acid has a strong action upon lead, which, if concentrated, it converts into a white oxide; but if diluted, it dissolves the metal, and forms nitrate of lead, which is crystallizable. Lime, and the alkalies decompose the nitric solution. Nitrate of lead decrepitates in the fire, and is fused with a yellowish flame upon ignited coals. Sulphuric acid will take lead from the nitric acid, falling down upon being added to it, combined with the metallic oxide. The muriatic acid carries down the lead in the same manner, and forms a muriate of lead formerly called *plumbum corneum*. This is soluble in water.

If the nitric acid, of the specific gravity of 1.260, be poured upon the red oxide of lead, 185 parts of the oxide are dissolved; but 15 parts remain in the state of a deep brown powder. This powder is the brown oxide of lead: it contains 21 per cent. of oxygen.

The muriatic acid, assisted by heat, dissolves a part

of the lead put into it, and oxidizes another part. The strong affinity of the oxides of lead for muriatic acid, causes them to decompose almost every substance in which this acid is found, by combining with it. Thus, when volatile alkali is obtained by distilling muriate of ammonia with the oxides of lead, the residuum is muriate of lead: the oxides of lead will even disengage the volatile alkali in the cold. Muriate of soda is decomposed if fused with litharge; the lead uniting as in the last-mentioned case with the muriatic acid, and forming a yellow compound for the manufacture and use of which, as a pigment, a patent has been obtained.

The acetous acid dissolves lead and its oxides. The white oxide of lead, known in commerce by the name of *white lead*, is prepared by its means. The lead is cast in thin plates, which are rolled up in the manner of a watch-spring, with a narrow space between each coil. They are then placed vertically in earthen pots, which contain a quantity of good vinegar, but their lower edge is prevented from coming in contact with the vinegar by suitable projections from the sides of the pots. The pots are then covered, and bedded in tan in a close apartment. The vapour of the acid slowly converts the surface of the lead into a white oxide, which is separated by shaking or uncoiling the plates. The plates are then re-submitted to the same process, until nearly consumed, when they are melted up, and cast over again. The white oxide thus obtained, is prepared for sale by washing it in water, and drying it in the shade: it is then called indiscriminately white lead or ceruse, though some only give the name of ceruse to its mixture with chalk. If white lead be dissolved in acetous acid, it affords a crystallizable salt or acetate, which, from its sweet taste, is called *sugar of lead*. From its effect in diminishing acidity, sour wines have been sweetened by the addition of white lead, a practice which merits the severest reprobation, as the oxides of lead are the most destructive poisons, in whatever way received into the animal system, whether in solution, by breathing the dust which

arises from them, or by working among them with the hands.

The oxides of lead dissolve in oils, of which they correct the rancidity, and, therefore, they have sometimes been added to the finer oils with fraudulent intentions. Linseed and other drying oils are rendered still more strongly desiccative by boiling upon oxide of lead.

Pure alkaline solutions corrode lead, and dissolve a small quantity of it.

Phosphoric acid, if heated with charcoal and lead, becomes converted into phosphorus, which combines with the metal. This phosphuret differs not much from common lead: it is malleable, and easily cut with a knife; but it sooner loses its brilliancy than common lead; and by fusion the phosphorus is burnt, and the lead left pure.

SILVER.

Silver is the whitest of all metals, and next to gold, it is the most malleable and ductile. Under the hammer, the continuity of its parts is not destroyed, until its leaves are not more than the $\frac{1}{100,000}$ of an inch thick; and it may be drawn into wire finer than a human hair.

The specific gravity of silver is 10.474; its hardness is 6.5. It continues melted at 28° of Wedgewood; but a greater heat is required to bring it into fusion. Its tenacity is such, that a wire of one-tenth of an inch in diameter, will sustain a weight of 270 pounds, without breaking.

Silver has neither smell nor taste. It is not altered by the contact of air, unless containing sulphurous vapours; but it may be volatilized by an intense heat, and Lavoisier oxidized it by the blow-pipe and oxygen gas. By exposing silver twenty times successively to the heat of a porcelain furnace, Macquer converted it into glass, of an olive-green colour.

Silver is found, in greater or less abundance, in almost all countries which contain mines; but the greatest quantities of it are obtained from the mines of Peru and

Mexico. The celebrated mine of Potosi, which is situated near the source of the Rio de la Plata, is one of the most considerable mountains of Peru; and this mountain is described by travellers as filled with veins of silver from the top to the bottom.

Silver is often found native in ramifications consisting of octahedrons inserted in each other, also in small interwinded threads, and in masses; but it is most commonly found in combination with sulphur.

Silver forms alloys with most of the metals. Copper is the metal with which it is alloyed for the purpose of coinage. The British coinage contains 11 ounces 2 pennyweights of fine silver in the pound troy. Copper stiffens silver, and increases its elasticity, but renders it less ductile.

The alloy of silver and zinc is granulated on its surface, and very brittle. Tin, also, in the smallest quantities, deprives silver of its malleability. Alloyed with lead, silver ceases to be sonorous and elastic.

Fine filings of silver, triturated with mercury in a warm mortar, form an amalgam, which by fusion and slow cooling, affords tetrahedral prismatic crystals, terminated by pyramids of the same form. The mercury cannot be separated from the silver, except by a much stronger heat than would be required to volatilize it alone.

The sulphuric acid dissolves silver, if concentrated and boiling, and the metal in a state of minute division. The action of the muriatic acid upon silver is very trifling, unless oxygenized.

The nitric acid, a little diluted, has a powerful action upon silver, of which it will dissolve half its weight. The solution is at first blue; this colour disappears when the silver is pure; but becomes green if it contains copper. If the silver contains gold, this metal separates in blackish coloured flocks. The solution is extremely corrosive, and destructive to animal substances. When the acid is fully saturated, it deposits crystals as it cools, and also by evaporation. Those crystals are called lunar nitre, or

nitrate of silver. By fusion, for which a gentle heat is sufficient, their water of crystallization is driven off; and also a part of the acid, by which they become a subnitrate; this forms the *lapis infernalis*, or lunar caustic of the surgeons; it is of a black colour, and usually cast in the form of small sticks. A heat a little above what is necessary for fusing the nitrate, separates the whole of the acid, and the silver is revived. Lunar caustic should be made of silver entirely free from copper, as the copper is poisonous to wounds.

The causticity of this and all other mineral solutions, is attributed to the strong propensity of the metal to assume the metallic state; in consequence of which, it readily parts with its oxygen to substances it is in contact with; and, therefore, such substances as are capable of receiving the oxygen, virtually undergo a combustion.

A solution of nitrate of silver in water, is perfectly free from colour; but it stains the skin, and all animal and vegetable substances, an indelible black. It is employed, in a weak state, to dye the human hair, and when mixed with a little gum-water, forms a *permanent ink* for marking linen. It is employed for staining marble and other stones.

Nitrate of silver is a most powerful antiseptic; a 12,000th part of it dissolved in water will render the water incapable of putrefaction, and it may be separated at any time by adding some common salt.

Silver is precipitated from its solution in nitric acid by muriatic acid, in the form of a white curd, which, when fused, forms a semi-transparent, and rather flexible mass, resembling horn; it was therefore anciently called *luna cornea* or *horn silver*, and is supposed to have given rise to some of the accounts we have of flexible glass. It is a *muriate of silver*, soon blackens in the air, and is scarcely soluble in water.

The muriatic acid does not dissolve silver, but has a strong affinity for its oxide, and as the muriate of silver is not very soluble in water, the nitrate of silver is em-

ployed as a re-agent, to discover the presence of muriatic acid in any liquid: for if it contains that acid, muriate of silver will fall down in a white cloud, on dropping nitrate of silver into it.

The nitric acid sold in the stores generally contains muriatic or sulphuric acid, or both; hence the nitrate of silver is employed to free the nitric acid from the two latter acids. For this purpose, nitrate of silver is poured into it by degrees, until no more precipitate is produced, after which it is rendered clear by filtering. Nitric acid thus purified, is called by artists *precipitated aquafortis;* but it still contains some silver, from which it cannot be freed except by distillation.

When mercury is added to the nitric solution of silver, a precipitation of the silver is formed, which, from its resemblance to vegetation, is called *arbor Dianæ*, or *tree of Diana.*

A few drops of nitrate of silver, laid upon glass, with a copper-wire in it, afford another beautiful precipitation of the silver, in the form of a plant.

Silver supplies a fulminating powder, incomparably more dangerous than any other: the nitric solution of fine silver is precipitated by lime-water; the water is decanted; and the oxide is exposed for two or three days to light and air. This dried oxide being mixed with ammonia, or volatile alkali, assumes the form of a black powder; decant the fluid, and leave the powder to dry in the open air. This powder is the fulminating silver, which, after having been once made, can no longer be touched; it must therefore be left in the vessel in which the evaporation was performed. It should never be made but in minute quantities, and not more than the fulmination of a grain should be attempted at once.

The avidity with which sulphur enters into combination with silver, is instanced by Proust, in its tarnishing when exposed in churches, theatres, and other places, much frequented by men. This tarnish soon becomes a real crust, which, on examination, is found to be a sulphuret of silver. It can only be detached by bending

the silver, or breaking the silver to pieces, and its colour is a deep violet, like the sulphuret of silver formed by fusion. Proust is of opinion that sulphur is constantly formed and exhaled by living bodies.

The sulphuret of silver is brittle, and more fusible than silver. By a sufficient heat alone, the sulphur is volatilized, and the metal entirely recovered.

NICKEL.

Nickel is a metal of greyish white colour, between that of tin and silver; but when not pure, it is reddish, which is the colour of its ore. It is both ductile and malleable, when cold and red-hot. Its specific gravity is 9.000, and its hardness is 8. It is not fused at a less heat than 150° of Wedgwood.

The ore of the nickel has been long known to the miners of Germany, where, from its resemblance to that of copper, it is called *kupper-nickel*, or false copper. Bergman was the first who discovered that it contained a peculiar metal.

Nickel is strongly attracted by the magnet, and attracts iron. On this account, it was supposed to contain iron; but Chenevix and Richter discovered that a very small portion of arsenic prevents nickel from being affected by the magnet. When it is not attractable, therefore, the presence of arsenic may be suspected. To separate arsenic from nickel, Chenevix boiled the compound in nitric acid, till the nickel was converted into an arseniate, decomposed this by a nitrate of lead, and evaporated the liquor not quite to dryness. He then poured in alcohol, which dissolved only the nitrate of nickel. The alcohol being decanted and evaporated, he re-dissolved the nitrate in water, and precipitated it by potass. The precipitate, well washed and dried, he reduced in a Hessian crucible, lined with lamp-black, and found it to be perfectly magnetic; but this property was destroyed again by alloying the metal with a small portion of arsenic.

The kupfur-nickel of the Germans, is the sulphuret of nickel, and besides generally contains arsenic, iron, and cobalt. This ore is roasted, to drive off the sulphur and arsenic, then mixed with two parts of black flux, put into a crucible, covered with muriate of soda, and heated in a forge furnace. The metal thus obtained, which is still very impure, may be dissolved in diluted nitric acid, and then evaporated to dryness; after this process has been repeated three or four times, the residuum must be dissolved in a solution of ammonia perfectly free from carbonic acid. Being again evaporated to dryness, it is now to be well mixed with two or three parts of black flux, and exposed to a violent heat in a crucible, for half an hour or more.

Richter says, that pure nickel is not liable to be altered by the atmosphere; hence it is better adapted than steel for compass needles.

By exposing nickel to heat with nitre, an oxide of it is obtained of a greenish colour, if the metal be impure; but if otherwise, brown; this oxide contains 33 parts in the 100 of oxygen.

The French manufacturers of porcelain are said to use the oxide of nickel in producing a delicate grass green. A hyacinthine colour may be given to flint-glass by the same oxide.

Proust observes, that a certain proportion of nickel increases the whiteness of iron, diminishes its disposition to rust, and adds to its ductility. In Birmingham, it is occasionally combined with iron and brass. The Chinese, also, employ it in conjunction with copper and zinc for children's toys. It is the difficulty of working this metal, rather than its scarcity, that renders it so little known. Equal parts of copper and nickel form a red ductile alloy. The alloys of it with tin and zinc are brittle. Equal parts of silver and nickel form a white ductile alloy. It does not amalgamate with mercury. Nickel is soluble with most of the acids, but the action of the sulphuric and muriatic is not considerable. The nitric and nitromuriatic acids are its proper solvents. The

nitric solution is of a fine green grass colour, and by evaporation affords green crystals in rhomboidal cubes.

Cronsted found that nickel combines with sulphur by fusion, and that the result is hard and yellow, with small brilliant facets; but the nickel which he employed was impure.

Nickel combines readily with phosphorus, either by fusion along with phosphoric glass, or by dropping phosphorus upon it while it is red-hot. The phosphuret of nickel is of a white colour, and when broken, exhibits the appearance of very slender prisms united together.

It is remarkable that all those bodies called meteoric stones, which have at different times fallen from the atmosphere, contain nickel.

COPPER.

Copper is of a pale red colour, inclining to yellow. It has a stypticand unpleasant taste, and emits, by friction, a disagreeable smell. Its hardness is 8; its specific gravity is 7.788. In point of malleability, it is not much inferior to silver. It is sometimes found native.

If copper be made red-hot, in contact with air, its surface rapidly oxidizes, and the oxide may be separated by the hammer, or by plunging the oxide into water. By the repetition of the process, another scale will be formed; and this may be continued, till the whole of the metal disappears. These scales are a *brown oxide of copper*, which contains 84 parts of copper, and 16 of oxygen. This oxide may be converted into a brown glass, by a strong heat.

When exposed to the air, copper becomes covered with a green crust, which is the *green oxide of copper*. This change takes place only at the surface, the oxide itself forming a defence from further change.

Filings of copper, thrown upon burning coals, burn with a greenish flame, and when the metal is kept in a greater heat than what is necessary for its fusion, it burns with a flame of the same colour.

Most of the alloys of copper have been already noticed. This metal, with iron, forms the *alderado*, or Keir's patent metal for window-frames, designed to combine elegance with strength. Copper unites very readily with antimony, and forms an alloy, distinguished by a beautiful violet colour.

Concentrated sulphuric acid dissolves copper by the assistance of heat, and the crystals of the solution, after adding water to it, form a *sulphate of copper*, generally called *blue vitriol.* If to this sulphate of copper be added a solution of arseniate of potass, a beautiful green precipitate is formed, called *Scheele's green*, or *mineral green.* Magnesia, lime, and the fixed alkalies, precipitate copper from its solution in sulphuric acid, in the form of an oxide.

The muriatic acid does not dissolve copper, unless concentrated and in a state of ebullition; the solution is green; the muriatic is caustic and astringent, fuses by a gentle heat, and congeals into a mass.

The nitric acid attacks copper with effervescence. A large quantity of nitrous gas is disengaged. The acid first oxidizes the metal, and then dissolves the oxide. The solution has a blue colour, much deeper than that by sulphuric acid, and affords crystals by slow evaporation. Lime precipitates the metal of a pale blue; fixed alkalies, of a bluish white. Volatile alkali throws down bluish flocks, which are quickly re-dissolved, and produce a lively blue colour in the fluid.

The acetous acid highly concentrated, dissolves copper; but when not concentrated, it only corrodes the metal, and forms the oxide called *verdigris.* This oxide, dissolved in vinegar, forms a salt called by the chemists *crystallized acetate of copper*, and in commerce distilled verdigris.

Copper is precipitated from its solution by iron. The iron is simply immersed in the solution; the acid seizes upon it, and abandons the copper. The copper obtained by this means is called *copper of cementation.* Sulphate of copper is frequently found in streams of water from copper mines; the quantity of salt which they contain is

not sufficient to reimburse the expense of evaporating the water to obtain blue vitriol; but by throwing waste pieces of iron into them, the salt is decomposed, and the copper is precipitated in a metallic form, because the sulphuric acid has a greater attraction for iron than copper. It appears in effect as if the iron was changed into copper, and to the superficial observer favours the idea that metals are transmutable. The streams of mines thus containing sulphate of copper are often as valuable as the ore itself.

All the salts of copper are poisonous; and copper vessels should therefore never be used to contain any vehicle capable of holding the metal in solution. In Sweden, the use of copper vessels for culinary purposes, has been prohibited by law, and a statue of the metal dedicated to the man, at whose solicitation it was obtained.

Sulphur combines with copper at a strong heat. Sulphuret of copper is brittle, softer than copper, of a black colour externally, and within of a leaden grey.

A phosphuret of copper may be formed by casting phosphorus upon red-hot copper. It has the hardness of steel, but is too brittle and refractory to be useful.

Prussic acid unites with the oxide of copper, and forms a brown pigment, superior, both in oil and water, according to the experience of Hatchet, to any other in use. It has a purple tinge, so as to form various shades of bloom or lilac when mixed with white, and which are not liable to fade as those made with lake. The best mode of preparing the prussiate of copper, is to dissolve the green muriate in ten parts of distilled water, and precipitate with prussiate of lime.

Fixed alkalies have some action on copper, with which they form a light blue solution; the effect is greatest in the cold.

Ammonia dissolves copper with much greater rapidity than fixed alkalies, whether it be in the state of metal or an oxide, and forms a beautiful blue solution. This solution, when recently made, is colourless if the

vessel be closed, but when the vessel is opened, the colour returns, gradually extending from the surface downwards.

Oils appear to have no action on copper, until they become rancid, in which case their disengaged acid corrodes the copper, and the oil assumes a bluish green colour.

IRON.

Iron is of a bluish white colour, highly elastic, sonorous, has a styptic taste, emits a peculiar odour when rubbed, and strikes fire with flint. In tenacity it exceeds all metals; wire of it, only one-tenth of an inch in diameter, sustaining a weight of 450 pounds without breaking. Its specific gravity is 7.788.

Iron is less malleable than gold, silver, or copper; it is of all the metals in common use the most difficult of fusion, but the nearer it approaches to fusion, the more malleable and ductile it becomes.

The hardness of iron, its great tenacity, the facility with which it may at a white heat be fashioned and welded, are the properties which render it so valuable.

Iron is attracted by the magnet or loadstone, and is itself capable of being rendered magnetic; but this property, after having been communicated to it, is retained only a short time, unless it be in the state of hard steel.

If suddenly plunged into cold water, while red-hot, it is rendered rather more rigid than before, but gradually cooling, renders it soft.

Iron is sometimes found native. In the museum of the academy of science at Petersburgh, is a mass of native iron, 1200 tons in weight.

Cast-iron is that which results from the fusion of the iron ore with charcoal: its peculiar properties are owing to its containing carbon, and other foreign matters.

Steel is iron deprived of all impurities except a small portion of carbon: it is more ductile than iron, and a finer wire may be drawn from it than any other metal.

Iron, united with about nine-tenths of charcoal, forms plumbago, or hyper-carburet of iron.

Iron has a greater affinity for oxygen than oxygen has for hydrogen; it therefore decomposes water by combining with its oxygen; which is the cause of its being easily altered by exposure to damp air or water.

The action of air, assisted by heat, converts a thick pellicle of the surface of iron into a black oxide, containing 25 per cent. of oxygen; and when this is hammered off, another is quickly formed. This black oxide is attracted in some degree by the magnet. If it be collected, and exposed to a strong heat under a muffle, it becomes a reddish brown oxide, containing 48 per cent. of oxygen. The yellow rust formed when iron is long exposed to damp air, is not a simple oxide, but contains a portion of carbonic acid. Proust only admits two stages in the oxidation of iron, viz. the green, and the brown, or red, and considers the other supposed oxides to be mixtures of these in various proportions.

The *green oxide* may be obtained by dissolving iron in sulphuric acid, and then precipitating it by potass. This oxide contains 27 parts of oxygen, and 73 of iron, in the 100. By exposure to the air, it is converted into brown oxide, which contains 18 parts of oxygen, as observed above.

Concentrated sulphuric acid scarcely acts on iron, unless it be boiling; but, if diluted with two or three times its weight of water, it attacks the metal immediately, and a strong effervescence ensues, without any heat but that produced by the addition of the water. It is the hydrogen gas of the water which escapes, the oxygen being employed in oxidizing the metal; which oxide the acid dissolves without being decomposed. If heat be applied, more iron still is dissolved. This solution yields, by evaporation, *sulphate of iron.* The common green copperas of commerce is this salt in a state of impurity. It is much more soluble in hot than in cold water; and, therefore, a saturated solution of it in hot water affords crystals in cooling, as well as by evaporation.

The substance called *martial pyrites* is a sulphuret of iron, and it is from the decomposition of it, that the

extensive demand for sulphate of iron is supplied. By fusion with iron, sulphur produces a compound of the same nature as pyrites.

The sulphuret of iron, as well as iron itself, burns rapidly, but without noise, when triturated in a metallic mortar with hyper-oxymuriate of potass. This mixture, in a heap, if struck with steel, detonates strongly, and gives out a red flame.

Sulphate of iron is decomposed by alkalies and by lime. Caustic fixed alkali precipitates the iron in deep green flocks, which are dissolved by the addition of more alkali, and form a red tincture. The mild alkali does not re-dissolve the precipitate it throws down, which is of a greenish-white colour. Distillation separates the acid from sulphate of iron, and leaves the brownish-red oxide called *colcothar*.

Astringent vegetables, such as gall-nuts, oak, tea, &c., precipitate a fine black fecula from sulphate of iron, and this precipitate remains suspended a considerable time in the fluid, by the addition of gum-arabic, and hence its utility as a writing ink. The well-known pigment called prussian blue, is likewise a precipitate afforded by sulphate of iron.

Sulphur combines with iron merely by the assistance of water; thus, if flowers of sulphur be mixed with iron filings, and made into a paste with water, it soon becomes hot, swells, and emits the well-known smell of hydrogen, with watery vapours. The mixture takes fire, if in considerable quantity, even although buried in the earth. It is a composition, therefore, which may be used to form an artificial volcano.

Concentrated nitric acid is rapidly decomposed by iron, a portion of the oxide of the acid oxidizes the iron, which oxide dissolves as it is formed, and the remainder of the acid passes off in nitrous gas. The solution is of a reddish brown, and deposits the oxide of iron after a certain time, particularly if exposed to the air. Diluted nitric acid affords a more permanent solution of iron, of a greenish, or sometimes of a yellow colour. Neither of

the solutions affords crystals, but both deposit the oxide of iron by boiling, at the same time that the fluid assumes a gelatinous appearance. This magma, by distillation, affords fuming nitrous acid, much nitrous gas, and some nitrogen, a red oxide being left behind.

Iron appears to be the only metal of which the solutions, or combinations with oxygen, are not of a noxious nature. The chalybeate waters form the best tonics which medicine possesses.

The muriatic solution of iron, like all other solutions of the same metal, is decomposed by lime and alkalies; but the precipitates are less altered, and may be easily reduced, especially such as are produced by the addition of caustic alkalies. Alkaline sulphurets, sulphuretted hydrogen gas, and astringents, also decompose this as well as the other solutions of iron.

Water charged with carbonic acid dissolves a considerable quantity of iron. Vinegar appears to have little or no effect upon iron, unless assisted by the air.

If equal parts of iron chippings, and phosphoric glass, be melted together, a phosphuret of iron is obtained, which is very brittle, and has a whitish fracture. Iron, in its crude state, frequently contains phosphorus, which renders cast-iron very refractory, and forms the kind called *cold-short iron*, which is malleable when hot, though brittle when cold.

Gold unites easily with iron, and becomes by this union harder and less malleable. In the proportion of six parts of gold and one of steel, the alloy may be beaten into plates without cracking. The iron is only partly separated by combustion in a glowing heat. Iron has a stronger attraction than gold for the oxy-muriatic and nitro-muriatic acids, and precipitates gold from these acids in its metallic state.

Silver combines readily with iron. A mixture of fourteen parts of silver, and two and a half iron, is more elastic than silver, attracts the magnet, and is not decomposed in a strong fire. A small portion of iron does not seem to injure the colour or malleability of the silver

Iron precipitates silver from all its solutions in acids; but this happens in the nitric only, when the acid is not completely saturated, or when nitrous gas is added. Muriate of silver is decomposed in the dry way by its distillation with iron filings.

Iron precipitates mercury in its metallic state from its solution in acids. Distil with oxymuriate of mercury, the muriate is decomposed, and fluid mercury produced.

Sulphate of iron precipitates mercury from its solution in nitric acid, in its metallic state.

Lead is precipitated from its solutions in acids by iron. Iron also precipitates nickel from its acid solutions, and in the dry way takes from it the sulphur which it contains.

Nickel has the strongest affinity for iron of all the metals, and is separated from it with the greatest difficulty. The alloy is fully as malleable, but less fusible than iron alone. Nickel is precipitated only in a very imperfect manner by iron from its solutions in acids.

Iron unites in close vessels with arsenic, which renders it more brittle, diminishes its attraction for the magnet, and is separated from it with difficulty.

When iron has been covered with tin, the tin appears to combine with it, and forms an alloy of greater depth than would readily be supposed; even a white heat is insufficient to separate the tin entirely, yet till the whole of it is removed, the iron will not weld.

TIN.

Tin is a white metal, intermediate between that of lead and silver; it has little elasticity; its taste is disagreeable, and it has a peculiar smell, which increases by friction. Its hardness is 6; its specific gravity 7.291; is susceptible of very little increase by hammering. Its purity is judged of by its levity, as it cannot be alloyed with any metal lighter than itself.

The malleability of tin is such, that it may be extended into leaves not more than the 2000th part of an inch

thick; the tin-leaf called *tin-foil*, is, however, twice this thickness. The tenacity of tin is but small; a wire, one-tenth of an inch in diameter, will support only about 49 pounds without breaking. Its flexibility is considerable; it may be bent several times without breaking, emitting at the same time a distinct crackling noise.

All the tin used in England is supplied by the mines of Cornwall, which furnish 3000 tons annually. Its ores occur most frequently in granite, but never in lime-stone. It is very rarely found native.

Chaptal says, that if tin be kept in fusion in a lined crucible, and the surface be covered with a quantity of charcoal to prevent its calcination, the metal becomes whiter, more sonorous, and harder, provided the fire be kept up for eight or ten hours.

The brilliant surface of polished tin soon becomes a little tarnished by exposure to the air, but the effect is very superficial and slight.

Mercury dissolves tin with great facility, and in all proportions. To make this combination, heated mercury is poured on melted tin; the consistence of the amalgam differs according to the relative proportions of the two metals.

Nickel united to tin, forms a white and brilliant mass. Half a part of tin, melted with two parts of cobalt, and the same quantity of muriate of soda, furnished Beaume with an alloy in small close grains of a light violet colour.

Equal parts of tin and bismuth, form a brittle alloy, of a medium colour between the two metals, and the fracture of which presents cubical facets.

Zinc unites perfectly with tin, and produces a hard metal, of a close-grained fracture. Its ductility increases with the proportion of tin.

Antimony and tin form a white and brittle alloy, which is distinguished from other alloys of tin, by its possessing a less specific gravity than either of the two metals by which it is formed.

In combining arsenic with tin, precaution must be

taken to prevent the arsenic from escaping by volatilization. Three parts of tin may be put into a retort with one-eighth part of arsenic in powder; fit on a receiver, and make the retort red-hot; very little arsenic rises, and a metallic lump is found at the bottom, containing about one-fifteenth part of arsenic. It crystallizes in large facets, is very brittle, and hard to melt.

If tin be kept in fusion, with access of air, its surface is speedily covered with a greyish pellicle, which is renewed as fast as it is removed. If this grey oxide be pulverized and sifted, to separate the uncalcined tin, and calcined again for several hours under a muffle, it becomes the yellow oxide of tin, called among artizans *putty of tin*, and extensively used in polishing glass, steel, and other hard bodies.

A white oxide of tin is used in forming the opake kind of glass called enamel. This composition is made by calcining 100 parts of lead and 30 parts of tin in a furnace, and then fluxing these oxides with 100 parts of sand and 20 of potass. This enamel is white, and is coloured with metallic oxides.

All the mineral acids dissolve tin, and it may be precipitated from its solutions by potass; but an excess of potass will re-dissolve the metal. Nitro-muriate of gold is a test for tin in solution, with which it forms a fine purple precipitate.

The sulphuric acid dissolves tin, whether concentrated or diluted with water. Part of the acid is decomposed, and flies off in the form of sulphurous acid gas. Heat accelerates the effect of the acid. Tin dissolved in sulphuric acid is very caustic.

The solution of tin in the nitric acid is performed with astonishing rapidity, and the metal is precipitated almost instantly in the form of a white oxide. If this acid be loaded with all the tin it is capable of calcining, and the oxide be washed with a considerable quantity of distilled water, a salt may be obtained by evaporation, which detonates alone in a crucible well-heated, and burns with a white and thick flame, like that of

phosphorus. The nitric acid holds but a very small quantity of tin in solution, and when evaporated for the purpose of obtaining crystals, the dissolved portion quickly precipitates, and the acid remains nearly in a state of purity. Nitric acid, much diluted, holds rather more tin in solution, but lets it fall by standing, or by the application of heat.

The muriatic acid dissolves tin, whether cold or hot, diluted or concentrated. If fuming and assisted by a gentle heat, the addition of the tin instantly causes it to lose its colour and property of emitting fumes, and a slight effervescence takes place. The acid dissolves more than half its weight of tin; the solution is yellowish, of a fetid smell, and affords no precipitate of oxide, like the sulphuric and nitric acids.

The oxymuriatic acid dissolves tin very readily, and without effervescence, because the metal quickly absorbs the superabundant oxygen from the acid, and requires no decomposition of the water to effect its oxidation.

Nitro-muriatic acid, made with two parts of nitric acid and one of muriatic acid, dissolves tin with effervescence. It is the solution of tin in this acid which the dyers employ to heighten the colour of their scarlet dyes. It is prepared by adding small portions of tin at a time to the common aquafortis of commerce; when the appearance of oxide is observed at the bottom of the jar, muriate of soda is added, by which its solution is effected. If the colour imparted by this solution is not bright, a little nitrate of potass is added to it.

The acetous, and most vegetable acids, have some action upon tin, particularly when aided by a gentle heat; but the solutions thus obtained, are not used in the arts.

Tin decomposes the corrosive muriate of mercury. It is for this purpose amalgamated with a small portion of mercury, and this amalgam being first triturated in a mortar with the corrosive muriate, the mixture is then distilled by a gentle heat. A colourless liquor first passes over, and is followed by a thick white vapour, which

issues with a kind of explosion, and covers the internal surface of the receiver with a very thin crust. The vapour becomes condensed into a transparent liquor, which continually emits a thick, white, and very abundant fume. It was formerly called the *fuming liquor of Libarius*, and is the combination of the muriatic acid and tin.

Tin has a strong affinity for sulphur; the sulphuret of tin may be formed by fusing the two substances together; it is brittle, heavier than tin, and not fusible. It has a bluish colour, a lamellated texture, and is capable of crystallizing.

The white oxide of tin combines with sulphur, and forms a compound called *aurum musivum*, or *mosaic gold*, which is much used for giving plaster of Paris the resemblance of bronze, and improving the appearance of bronze itself. It is, also, occasionally used to increase the effects of electrical machines. Chaptal recommends for preparing it the process of the Marquis de Bouillon, who directs an amalgam to be formed of eight ounces of tin and eight ounces of mercury. In forming the amalgam, a copper mortar is heated, and the mercury poured into it, after which the tin is added in a state of fusion, and the mixture triturated till cold. Six ounces of sulphur and four of muriate of ammonia, are then mixed, and the whole put into a matrass, which is to be placed in a sand-bath, and heated to such a degree as to cause a faint ignition in the bottom of the matrass. The fire must be kept up for three hours. The aurum musivum obtained by this process is usually excellent; but if, instead of placing the matrass on the sand, it be immediately exposed upon the coals, and strongly and suddenly heated, the mixture will take fire, and a sublimate will be formed in the neck of the vessel, which consists of the most beautiful aurum musivum that can be prepared.

The mercury and muriate of ammonia are not in strictness necessary to the production of aurum musivum. Eight ounces of tin dissolved in muriatic acid, precipi-

tated by the carbonate of soda, and mixed with four ounces of sulphur, will produce a fine aurum musivum, but without the property of exciting electrical machines.

A phosphuret of tin may be formed by melting in a crucible equal parts of tin and phosphoric glass, or by throwing small pieces of phosphorus into melted tin. The phosphuret of tin may be cut with a knife; it extends under the hammer, but separates into laminæ. When newly cut, it has the colour of silver; its filings resemble those of lead, and the phosphorus takes fire when they are thrown upon burning coals.

ZINC.

Zinc is a bluish white metal; its specific gravity is 7.190; its hardness 6. It is distinguished by the singular property of being neither malleable nor ductile, at common temperatures, but of acquiring both these qualities at the temperature of 210° to 300°. It has neither taste nor smell. It melts at the heat of about 700.

Zinc, at a red heat, burns with a bright white flame, and throws out white flakes, called *flowers of zinc*. These flowers are the white oxide of the metal; they are not volatile, but are merely driven off by the force of the combustion. They contain more oxygen than the grey oxide, which forms on the surface of the metal when it is heated to fusion. The white oxide of zinc may be converted into a yellow glass by a very violent heat.

Zinc combines with most of the metals. With gold it combines in all proportions. The alloy is very hard and white when the metals are in equal proportions, and takes a fine polish, without being very liable to tarnish. One part of zinc is said to destroy the ductility of 100 parts of gold.

The alloy of silver and zinc is also brittle. Platina unites with zinc, and forms a brittle fusible alloy, tolerable hard, and of a bluish white colour, not so clear as that of zinc.

One part of zinc, and two and a half of mercury form by fusion an amalgam which becomes solid. It is used to excite electrical machines.

The well-known alloy called brass, which is formed of zinc and copper, is usually formed by cementing copper in a close crucible with calamine, an ore which contains zinc in the state of an oxide.

Tin and zinc combine readily; the alloy is harder than tin: lead and zinc also form alloys which are harder than lead. Two parts of lead and three of zinc form a hard alloy, which bears hammering without extending.

Iron and zinc have some affinity, as iron may be coated with zinc instead of tin, for culinary vessels. The solutions of zinc which may happen to be obtained, are not dangerous like those of lead.

If water be thrown upon ignited zinc, a part of it it decomposed: the oxygen converts part of the metal into an oxide, and hydrogen gas escapes.

Sulphuric acid dissolves zinc without heat. A salt may be obtained by evaporating the solution; this salt which is a sulphate of zinc, is known by the name of white vitriol; it has a strong styptic taste.

The nitric acid powerfully attacks zinc, and produces much heat; and a great part of the acid is decomposed; but crystals may be obtained by the slow evaporation of the residue. This salt, or nitrate of zinc, is deliquescent; it melts upon heated coals, and decrepitates, producing a slight reddish flame. If it be exposed to heat in a crucible, it emits red vapours, assumes the consistence of a jelly, and preserves this softness for a considerable time. The nitric solution of zinc is very caustic.

Muriatic acid also acts strongly upon zinc, with the disengagement of much hydrogen gas. The solution, by evaporation, does not crystallize, but assumes the consistence of a jelly, which if distilled, allows some of the acid to escape, and part of the muriate sublimes.

Most of the metallic and vegetable acids dissolve zinc which is precipitated from its solution by earths and al

kalies; the latter re-dissolves the precipitate, if added in excess.

Sulphur cannot be made to combine with metallic zinc; but it combines readily with the oxide of zinc.

Zinc may be combined with phosphorus by casting small pieces of phosphorus upon the melted metal, which should be covered with tallow or rosin to prevent its oxidation. Phosphuret of zinc is white, with a shade of bluish grey, has a metallic lustre, and is a little malleable.

Zinc also combines with carbon, and forms a carburet of zinc. It generally contains a small portion of carbon.

POTASSIUM.

The fixed alkalies, potass and soda, are found not to be simple bodies, as had once been supposed, but oxides, each of them containing a peculiar metal in combination with oxygen. They were analyzed by Sir H. Davy, in a course of experiments which that distinguished chemist undertook with the express view of discovering their nature. He succeeded by means of the galvanic apparatus in the following manner.

In his first experiments he acted upon aqueous solutions of potass and soda, by a powerful voltaic combination, but in this way he only obtained the decomposition of the water of the solution. He then acted upon these alkalies in a state of igneous fusion. The potass was contained in a platina spoon, and was kept perfectly fused in a strong red heat, by means of a stream of oxygen gas, from a gasometer applied to the flame of a spirit-lamp. The spoon was preserved in communication with the positive side of the battery of the power of 100 plates of 6 inches, highly charged, and the connection from the negative side was made by a platina wire. The advantage of this arrangement over the aqueous solution was soon apparent. The potass seemed to be a conductor in a high degree, and as long as the communication was preserved, a most intense light was exhibited at the negative wire, and a column of flame, which

seemed to be owing to the development of combustible matter, arose from the point of contact. When the order was changed, so that the platina spoon was made negative, a vivid and constant light appeared at the opposite point; there was no effect of inflammation around it, but aeriform globules, which inflamed in the air, rose through the potass.

As the products of the decomposition, which evidently appeared to have taken place in the above experiment, could not be collected, Sir H. Davy determined to apply the galvanic electricity to the alkali in its usual state. A small piece of potass, moistened a little by the breath, was placed upon an insulated disc of platina, connected with the negative side of a battery consisting of 100 plates of 6 inches, and 150 of 4 inches square, in a state of intense activity, and a platina wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. The whole apparatus was in the open air. Under these circumstances, a vivid action was soon observed to take place. The potass began to fuse at both its points of electrization, and small globules, having a high metallic lustre, and precisely the same in characters to mercury, appeared, some of which burnt with explosion and bright flame. These globules are the basis of potass, which has received the name of *potassium*, and appears fully entitled to rank among the metals, as we shall proceed to show.

It next became a matter of considerable difficulty to preserve and confine the basis of potass, in order to examine its properties. Sir H. Davy found, at length, that in recently distilled naphtha it may be preserved for some days, and that its physical properties may easily be examined in the atmosphere, when it is covered with a thin film of this liquid.

Potassium, at the temperature of 60°, is only imperfectly fluid; at 70° it becomes more fluid; at 100° its fluidity is perfect, so that different globules may easily be made to run into one. At 50° it becomes a soft and malleable solid, which has the lustre of polished silver

at about the freezing point of water, it becomes hard and brittle, and when broken in fragments, exhibits a crystallized texture, of a perfect whiteness and high metallic splendour. To be converted into vapour, it requires a temperature approaching to that of a red heat. It is an excellent conductor of caloric and of electricity.

Potassium will not sink in doubly distilled naphtha, the specific gravity of which is 770. Its specific gravity is to that of mercury as 10 to 223, which gives a proportion to that of water nearly as 6 to 10, so that it is the lightest fluid body known. Its levity is the physical property in which it differs most materially from the rest of the metals; yet between the lightest and heaviest of the established metals, the difference is not much less, than between the lightest of the established metals and potassium.

When potassium is introduced into oxymuriatic acid gas, it burns spontaneously, with a bright red light, and muriate of potass is formed. When thrown upon water it decomposes with great violence; an instantaneous explosion is produced, with a brilliant flame, and a solution of pure potass is the result. When a globule is placed upon ice, not even the solid form of two substances can prevent their union; for it instantly burns with a bright flame, and a deep hole is made in the ice which is found to contain a solution of potass. When a globule is dropped upon moistened turmeric paper, it instantly burns, and moves rapidly upon the paper, as if in search of moisture, leaving behind it a deep reddish-brown trace.

So strong is the attraction of the basis of potass for oxygen, that it discovers and decomposes the small quantities of water contained in alcohol and ether, even when they are carefully purified.

When potassium is thrown into the mineral acids, it inflames, and burns on the surface.

In sulphuric acid, sulphate of potass is formed; in nitrous acid, nitrous gas is disengaged, and nitrate of

potass is formed. When pressed upon a piece of phosphorus, there is a considerable action; the two substances become fluid together, burn, and produce phosphate of potass.

When a globule of potassium is made to touch a globule of mercury about twice as large, they combine, with considerable heat. The compound is fluid at the temperature of its formation, but when cool, it appears as a solid metal, similar in colour to silver. If this alloy be exposed to the air, it rapidly absorbs oxygen; potass, which deliquesces is formed, and in a few minutes the mercury is found pure and unaltered. When a globule of the amalgam is thrown into water, it rapidly decomposes it with a hissing noise; potass is formed, hydrogen disengaged, and the mercury remains free.

The amalgam of potassium and mercury dissolved all the metals that were exposed to it; and in this state of union mercury acts on iron and platina.

Potassium combines with fusible metals, and the alloy has a higher point of fusion than the fusible metal.

Potassium readily reduces the metallic oxides, when heated in contact with them. It decomposes common glass by a gentle heat, and at a red heat effects a change even in the purest glass.

From a variety of experiments, Professor Davy concludes, that 100 parts of potass, consist of about 84 basis, and 16 oxygen.

SODIUM.

When soda is exposed to the action of galvanic electricity, in the same manner as the potass, in the experiment above stated, a metal is obtained which is the basis of the alkali, and is called sodium.

Sodium is white, and opaque, and when examined under a film or naphtha, has the lustre and general appearance of silver. It is exceedingly malleable, and is much softer than any of the common metallic substances. A globule of it only one-tenth of an inch in diameter, is easily spread over the surface of a quarter of an inch,

and this property does not diminish when it is cooled to 32° of Fahrenheit.

By strong pressure, globules of sodium may be made to adhere and combine into one mass; so that the property of welding, which belongs to iron and platina at a white heat only, is possessed by this substance at common temperatures.

Sodium conducts caloric and electricity in a similar manner to potassium, and small globules of it inflame by the voltaic electrical spark, and burn with bright explosions. It is preserved under distilled naphtha in the same manner as potassium.

Its specific gravity is smewhat less than that of water, being as .9348 to 1. It is therefore heavier than potassium; but the difference is so small, that we place them in the order in which they were discovered.

Sodium has a much higher point of fusion than potassium: its parts begin to lose their cohesion at about 120°, and it is a perfect fluid at about 180°; so that it readily fuses under boiling naphtha.

But, though so easily fused, it remains in a state of ignition at the point of fusion of plate glass.

The chemical phenomena of sodium are not very different from those of potassium. When exposed to the atmosphere, it immediately tarnishes, and becomes covered with a white crust, which deliquesces much more slowly than that furnished by potassium.

The flame that sodium produces in oxygen gas is white, and it sends forth bright sparks, occasioning a very beautiful effect. In common air, it burns with light of the colour of that produced during the combustion of charcoal, but much brighter.

When introduced into oxymuriatic acid gas, it burns vividly, with numerous scintillations of a bright red colour. The substance produced by this combustion is muriate of soda, (common salt.)

When thrown upon water, it produces a violent effervescence, with a loud hissing noise; it combines with the oxygen of the water to form soda, and the hydrogen of

the water is disengaged. This experiment exhibits no luminous appearance. With hot water, the decomposition is violent, and a few scintillations are observed at the surface of the fluid; but this is owing to small particles of sodium, which are thrown out of the water sufficiently heated to burn in passing through the atmosphere.

Sodium decomposes the water of alcohol and ether, in the same manner as the water in these fluids is decomposed by potassium.

It acts upon strong acids with great energy. With nitrous acid, a vivid inflammation is produced: with muriatic and sulphuric acids, there is much heat, but no light.

Sodium, in its action upon sulphur, phosphorus, and the metals, scarcely differs from potassium. It combines with sulphur in close vessels filled with the vapou. of naphtha, with a vivid light, heat, and often with explosion. The sulphuret is of a deep grey colour.

The phosphuret has the appearance of lead, and forms phosphate of soda by exposure to air, or by combustion.

One-fortieth part of sodium renders mercury a fixed soda of the colour of silver, and the combination is attended with a considerable degree of heat.

It makes an alloy with tin without changing its colour, and it acts upon lead and gold when heated. In its state of alloy, it is soon converted into soda by exposure to the air.

Sir H. Davy concluded, that 100 parts of soda consist of 76 or 77 of sodium, and 24 or 23 oxygen.

In concluding the communication to the Royal Society, from which the preceding view of the properties of potassium and sodium is derived, Sir H. Davy justly remarks, that an immense variety of objects of research is presented in the powers and affinities of the new metals produced from the alkalies. In themselves they will undoubtedly prove powerful agents for analysis; and having an affinity for oxygen stronger than any other

known substances, they may possibly supersede the application of electricity to some of the undecomposed bodies.

In sciences kindred to chemistry, the knowledge of the nature of alkalies, and the analogies arising in consequence, will open many new views: they may lead to the solution of many problems in geology, and show that agents may have operated in the formation of rocks and earths which have not hitherto been suspected to exist.

BISMUTH.

Bismuth is known among artisans by the name of *tinglass*. It is a metal of laminated texture, a pale yellowish red colour; not ductile or malleable, but reducible to powder under the hammer. Its specific gravity is 9.822; its hardness is 6. It melts at the heat of 460°.

Bismuth sublimes when heated in close vessels; when allowed to cool slowly, it crystallizes. It is not altered by water, and though it tarnishes by exposure to the air, it is not much changed.

Bismuth combines with most of the metals; its general effect is to increase their fusibility. The alloy of bismuth and platina is very brittle. When exposed to the air, it assumes a purple, violet, or blue colour. The bismuth may be separated by heat.

Equal parts of bismuth and gold form a brittle alloy, not much paler than gold.

Equal parts of bismuth and silver form a brittle alloy but less so than the last. The specific gravity of this and the last alloy is greater than intermediate.

The amalgam of mercury and bismuth is more fluid than mercury, and has the property of dissolving lead, without having its fluidity lessened.

The alloy of copper and bismuth is not so red as copper.

A small portion of bismuth renders tin brighter, harder, and more sonorous: it is often therefore an ingredient in pewter. Bismuth remarkably increases the fusion of

this metal: when the alloy consists of equal parts, it melts at 280°.

Bismuth does not combine with zinc, and its alloy with iron, cobalt, arsenic, and antimony, is unknown.

The alloy of lead and bismuth is of a dark grey colour a close grain, and very brittle. Eight parts of bismuth, five of lead, and three of tin, form a metal which melts at a heat not exceeding that of boiling water. Teaspoons are made of this alloy, to surprise those unacquainted with their nature: they have the appearance of common teaspoons, but are melted in hot water.

Bismuth expands as it cools, for which reason it is well adapted for casting, and is sometimes added in the composition for printers' types, particularly the smaller sizes, where a sharp perfect impression from the mould is of great importance.

Bismuth may be used in cupellation instead of lead, and would for this purpose be preferable to lead, were it not so much more scarce and expensive.

This metal, when exposed to a red heat, burns with a faint blue flame, and emits yellowish fumes, which when condensed, form what are called *flowers of bismuth*. This oxide is converted into a greenish glass by strong heat.

The sulphuric acid, when concentrated and boiling has a slight action on bismuth. Sulphurous acid gas escapes, and part of the metal is converted into a white oxide. The sulphate of bismuth does not crystallize, and is very deliquescent.

The nitric acid exerts a vehement action on bismuth. Much heat, with a large quantity of nitrous gas, is evolved. The solution, when saturated, affords crystals as it cools. This nitrate detonates weakly, and leaves a yellow oxide behind, which effloresces in the air.

The action of muriatic acid upon bismuth is very slow and inconsiderable; and even for this effect the acid must be highly concentrated.

Water precipitates bismuth from all its solutions: the precipitate, which is a beautiful white, is when well

washed, used as a cosmetic, under the name of magistery of bismuth. It has, however, the disadvantage of turning to a dark colour, by a very slight degree of sulphurous effluvia; and, as the metal resembles lead in its noxious qualities, and is seldom free from arsenic, like other mineral cosmetics, it cannot be used without danger to the skin and the constitution.

Magistery of bismuth is sometimes mixed with pomatum, for the purpose of staining the hair of a dark colour.

Sulphur combines readily with bismuth by fusion. The sulphuret of bismuth is of a bluish-grey colour, and crystallizes into beautiful tetrahedral needles. It contains 15 parts in 100 of sulphur.

Phosphorus, dropped into melted bismuth, forms a phosphuret of the metal, which only contains about 4 parts in the 100 of phosphorus.

ARSENIC.

Arsenic is of a brilliant bluish-white colour, a laminated texture, fusible, and very brittle. Its specific gravity is 8.310; its hardness, 7. It soon tarnishes by exposure to the air, becoming first yellowish, and then black; but, if immersed in alcohol, its metallic lustre suffers no diminution. It is one of the most combustible metals, burns with a blue flame and the smell of garlic, and sublimes in a state of arsenious acid. It is, in all states, one of the most virulent poisons known.

When exposed to the air, arsenic is gradually converted, by combining with oxygen, into a greyish-black substance, which is the *grey oxide of arsenic*. If this oxide be sublimed, the sublimate, having combined with an additional dose of oxygen, forms the *white oxide of arsenic*, which contains 7 parts in the 100 of oxygen. This oxide glitters as if it were powdered glass; it has an acid taste, which terminates in an impression of sweetness: it has a smell like garlic. This is the state in which the arsenic of commerce is met with.

The white oxide of arsenic may be converted into the metallic state by heating it with the oils, tallow, or charcoal, in close vessels; but this is seldom necessary in the arts, as it enters into combination with other metals from the state of oxide. This oxide is soluble in 80 parts of water, at the temperature of 60°, and in 15 parts of boiling water. When the solution is evaporated, the oxide crystallizes; and when heated to 283° it sublimes; if heated in close vessels, it becomes pellucid like glass, but soon recovers its former appearance by exposure to the air. The specific gravity of the glass is 5.000; of the white oxide 3.706.

Almost the whole of the arsenic which is sold, is obtained from the cobalt ores of Saxony, where long winding flues are constructed, to the sides of which the sublimed arsenic attaches itself.

Arsenic unites with most of the metals by fusion, and a very small quantity of it has often a material effect.

Platina and arsenic form a brittle and fusible alloy; the arsenic may be driven off by a great heat.

Gold by fusion takes up about $\frac{1}{60}$th of arsenic, with which it forms a pale and brittle alloy.

Silver takes up one-fourteenth of arsenic.

Copper combines with five-sixths of arsenic, forming a white, hard, and brittle alloy; when the quantity is small, it is both ductile and malleable; it is called *white tombac*, and is much used in the manufacture of buttons.

Iron is capable of combining with more than its own weight of arsenic; the alloy is white, brittle, and capable of crystallization.

The alloy of tin and arsenic is harder and more sonorous than tin, and has nearly the same external appearance as zinc. Tin often contains a small quantity of arsenic.

Lead takes up one-sixth of arsenic. The alloy is brittle and dark coloured.

Zinc takes up one-fifth of arsenic, antimony one-eighth, and bismuth one-fifteenth.

Upon the whole, the effect of arsenic is, to whiten the

red and dark coloured metals; to give brittleness to the ductile; to increase the fusibility of the refractory, and to render less fusible the rest. It is added to the compositions of the mirrors of reflecting telescopes, to increase the density of the compound.

The sulphuric acid, boiled on the oxide of arsenic, dissolves it; but the oxide precipitates as the solution cools.

The nitric acid dissolves the oxide of arsenic, by the assistance of heat, and forms a deliquescent salt.

The action of muriatic acid upon arsenic is very feeble, whether assisted by heat or in the cold. The sublimed muriate or butter of arsenic, is formed by mixing equal parts of the yellow oxide of arsenic, and corrosive muriate of mercury, and distilling with a gentle heat; in the receiver will be found a blackish corrosive liquor, which forms the sublimed muriate of arsenic.

Potass, boiled on the oxide of arsenic, becomes brown, gradually thickens, and at last forms a hard brittle mass, which is deliquescent arsenical salt. Soda affords, by the same treatment, a product nearly similar.

The combination of arsenic and sulphur is often found native, of a fine yellow colour; it is then called *orpiment;* this yellow sulphuret of arsenic may be prepared artificially, by mixing sulphur with the white oxide of arsenic, and heating them. It contains about 20 parts of arsenic in the 100. If a stronger heat be applied, so as to fuse this sulphuret, it assumes a scarlet colour, and forms the compound called *realgar*, which contains 80 parts of arsenic in the 100. It is the red sulphuret of arsenic. Realgar is occasionally found native, as well a orpiment. Lime and the alkalies decompose these sul phurets.

The phosphuret of arsenic may be found by putting equal parts of phosphoret and arsenic into a sufficient quantity of water, and keeping the mixture moderately hot some time. It is black and brilliant, and ought to be preserved in water.

The oxide of arsenic promotes the vitrification of

earths, but the glasses into which it enters are liable to tarnish.

The workmen employed in the mines which produce arsenic, are subject to violent complaints, and premature death. When this deleterious mineral has been swallowed, the sulphuret of potass (liver of sulphur) dissolved in water, is prescribed as the most effectual antidote. Arsenic, whether alone or in a mixture, may be distinguished by throwing it upon burning coals; as it will afford white fumes and the smell of garlic.

ANTIMONY.

Antimony is a brittle metal, of a white colour, inclining to grey, a laminated texture, exceedingly brittle, and neither malleable nor ductile. It may be reduced to powder. It has some taste, but no smell. Its specific gravity is 6.860; its hardness, 6.5. It tarnishes but little by the action of the air or water. It melts at a low red heat, or 809°; and, if the heat be much increased, it is volatilized in white fumes. This white oxide of antimony was formerly called *argentine snow*, or *flowers of antimony*.

If antimony be brought to a white heat, and then shaken, it takes fire, with a kind of explosion. If fused on charcoal before the blow-pipe, and thrown into the air, it divides into globules, and burns with a brilliant white light as it falls to the ground.

The antimony of commerce is found in two states—that of crude antimony, and in the metallic state. Crude antimony is the sulphuret of this metal, and is the only ore of it which is obtained in sufficient quantity to be wrought. Metallic antimony, better known by the name of *regulus*, is crude antimony deprived of its sulphur. If iron filings be fused with crude antimony, they combine with its sulphur, and the antimony is obtained pure. One-fifth of iron will combine with all the sulphur by which this metal is mineralized. In the large way, antimony is obtained by melting calcined antimony with

dried wine-lees, in a reverberatory furnace, and the sulphur is often not wholly removed from it. Sulphuret of antimony contains 26 parts in the 100 of the metal.

Antimony will enter into combination with most of the metals. With platina, it affords a brittle alloy, which is much lighter than platina. The platina cannot afterwards be separated from it by heat.

Gold may be combined with antimony, by fusing them together; and the antimony may be separated by an intense heat.

Silver and antimony form a brittle alloy, the specific gravity of which is greater than intermediate between the specific gravities of the two metals.

Mercury does not combine freely with antimony. Gellert succeeded by using hot mercury, and covering the whole with water.

Equal parts of lead and antimony, form a porous and brittle alloy; three parts of lead and one of antimony is the best composition for printing-types; and of all the alloys of antimony is the most useful. It forms a hard alloy, scarcely malleable, but so brittle as to break without bending, unless in very slender pieces; when properly prepared, its fracture has the appearance of that of cast-steel. In fusing the two metals, the antimony should be well mixed by stirring, as from its levity it will float on the lead; if the mixture has not been complete, the alloy breaks with brilliant facets. This alloy is more fusible and fluid than either of the metals separately, and as antimony expands in cooling, it takes a sharp impression of a mould. Bismuth is sometimes added to increase this property, as well as the fusibility but this metal is too costly to be added in any useful proportion, except for the smallest types. The antimony should be completely freed from sulphur, otherwise the types made of it undergo a spontaneous decomposition, easily break, and are covered with a black crust.

Twelve parts of lead and one of antimony, form an alloy very malleable; yet much harder than lead; 16 parts of lead and one of antimony, form an alloy which does not differ from lead, except in being rather harder

Copper combines readily with antimony; the colour of the alloy is a beautiful violet, and its specific gravity is greater than intermediate.

The alloy formed by iron and antimony is brittle and hard; its specific gravity is less than intermediate. The disposition of iron to receive magnetism, is much impaired by antimony.

The alloy of tin and antimony is harder than tin white, and brittle; the specific gravity is less than intermediate, yet the combination is so intimate, that it is scarcely possible to separate the antimony from the tin. A small portion of antimony is added with tin to form pewter.

Le Sage analyzed some nails intended for ship-building, and found them to consist three parts tin, two of lead, and one of antimony. These nails could be made to penetrate oak boards, and were not acted upon by sea-water.

The alloy of zinc and antimony is brittle.

Pure pewter has some action upon antimony, for it becomes purgative by standing in a vessel made of this metal.

Sulphuric acid, boiled upon antimony, is slowly decomposed. Sulphurous gas escapes, and sulphur, itself, by continuing the process. The sulphate of antimony is deliquescent, and decomposed by the fire.

The nitric acid is decomposed by antimony very readily; a considerable part of the antimony is oxidized, and part of the oxide is dissolved. This oxide is very white, and difficult of reduction.

The muriatic acid acts freely upon antimony, except by long digestion. The muriate of antimony, obtained by evaporation, is very deliquescent: it is fusible in the fire, and volatile.

Two parts of corrosive muriate of mercury, and one of the muriate of antimony, distilled by a gentle heat, afford the common *butter of antimony*, or sublimed muriate of antimony. This preparation is fluid at a gentle heat; by plunging the vessel which contains it into hot water, it becomes sufficiently fluid to pour out.

When butter of antimony is dropped into water, part of the metal, in the form of an oxide, is thrown down in a white powder. This substance is called *powder of algaroth*, which acts as a strong purgative.

If sulphuret of antimony be melted, and the heat continued, the sulphur sublimes, and the antimony is converted into a grey oxide; this oxide may likewise be obtained by powdering metallic antimony, and then submitting it to calcination. The oxide will combine with $\frac{4}{100}$ of sulphur, and this compound forms, by fusion, a glass called the *glass of antimony*.

Antimony supplies medicine with some of the most active and valuable remedies. The acid of tartar forms with it the preparation called *emetic tartar*, the new name of which is *antimoniated tartrate of potass:* it is composed of 56 parts tartrate of antimony, 36 tartrate of potass, and 8 of water.

The alkalies and lime decompose the antimoniated tartrate of potass.

The alkalies alone have no perceptible action on antimony, but the alkaline sulphurets dissolve it completely. Kermes' mineral, a medicine formerly of great celebrity, is a red sulphuretted oxide of antimony. It is prepared by boiling together half a pound of the sulphuret of antimony in powder, and two pounds of potass, in eight pints of pure water, for fifteen minutes; stirring the mixture with an iron spatula; and then expeditiously filtering it whilst it is hot. The liquor is now suffered to stand in a cool place, where it soon deposits a powder that must be repeatedly washed, first with cold, and afterwards with hot water, till deprived of taste. The antimony may be used again, until entirely consumed. According to the quantity which is taken, Kermes' mineral operates as an emetic, purgative, sudorific, or expectorant; its active properties render half a grain in most cases sufficient at a time.

Phosphorus, thrown in small pieces upon melted antimony, combines with it. The phosphuret of antimony is of a white colour, brittle, and appears laminated when broken.

TELLURIUM.

Tellurium is a recently discovered metal, nearly white like tin, but varying a little to the greyness of lead. Its fracture is laminated. It is extremely brittle, and nearly as fusible as lead. When heated with the blow-pipe upon charcoal, it burns with a very lively flame, of a blue colour, inclining at the edges to green. It is so volatile as to rise entirely into a whitish grey smoke, and exhales an odour like that of radishes. The smoke condenses into a white oxide. Its specific gravity is 6.115.

Klaproth, who discovered this metal, found it in an ore called the auriferous ore, otherwise *aurum paradoxicum*, which is obtained in Transylvania, and which contains but a very small quantity of gold.

Tellurium amalgamates with mercury by trituration. It is oxidized and dissolved in the principal acids. To sulphuric acid it gives a deep purple colour, and if this acid has been diluted with two or three parts of water, and a little nitric acid added, a considerable portion of tellurium will dissolve in it, and the solution will not be decomposed by water. The solution in sulphuric acid alone is separated in black flakes, and heat throws down a white precipitate.

With nitric acid, tellurium forms a colourless solution, which remains so when diluted, and affords slender, dendritic crystals by evaporation.

Tellurium dissolves in nitro-muriatic acid; the solution is transparent, and the addition of water precipitates a white powder, which is soluble in muriatic acid. Alcohol produces a similar precipitate.

Iron, tin, zinc, and antimony, precipitate tellurium from its acid solutions in a metallic state, under the form of small black flakes, which resume their splendour by friction, and which on burning charcoal rapidly melt into a metallic button.

The alkalies throw down from the solutions of tellurium, a white precipitate, which is soluble in all the acids, by an excess of the alkalies or their carbonates

TUNGSTEN.

Tungsten is externally of a brown colour, internally of a steel grey. Its specific gravity is 17.600, and it is extremely difficult of fusion.

This metal is in Sweden obtained from an ore in which its oxide exists in combination with lime; in Germany and England, it may be obtained from a mineral called wolfram, in which it exists in combination with iron. The oxide of tungsten has acid properties, and is therefore called *tungstic acid.*

D'Elhuyart found that wolfram contained $\frac{65}{100}$ of tungstic acid; the rest of it consisted of iron, manganese, and tin. This acid substance being mixed with charcoal powder, was violently heated in a crucible: after it had cooled, a button of metal was found of a dark brown colour, which crumbled to pieces between the fingers. On viewing it with a glass, it was found to consist of a congeries of metallic globules, some of which were as large as a pin head. These globules were the tungsten; the charcoal had combined with the oxygen of the acid substance, and left the metal pure. When heat is applied with access of air, tungsten is converted into a yellow powder, composed of 80 parts of tungsten, and 20 of oxygen. This is the *yellow oxide of tungsten*, or *tungstic acid.*

Vauquelin considers that the substance formed by combination of tungsten with oxygen, does not possess the properties generally attributed to acids; since it is insoluble in water, does not change the blue vegetable colours, and has no apparent savour. He advises it therefore to be called merely an oxide of tungsten, observing that Scheele, who regarded it as an acid, never obtained it but in a triple combination, which possesses acid properties.

Morveau asserts that the oxide of tungsten renders vegetable colours so fixed as not to be acted upon by the oxymuriatic acid.

Neither the sulphuric, the nitric, nor the muriatic acid dissolves either tungsten or its oxide.

The alloys of tungsten, and the uses to which the metal itself may be applied, appear to be little known.

Solutions of caustic potass, soda, and ammonia, dissolve the oxide of tungsten, even in the cold, forming tungstate of potass, soda, and ammonia.

Tungsten refuses to unite with sulphur.

A tungstate of magnesia is formed, by mixing oxide of tungsten with carbonate of magnesia and water, boiling the mixture, and straining it. An acid will precipitate a white powder; and, by evaporation, a white salt is obtained, which crystallizes in little bright spangles, and is unchangeable in air.

RHODIUM.

Rhodium is one of the new metals obtained from grains of crude platina. Its specific gravity is about 11. It is not malleable, and has never been perfectly fused alone. Sulphur and arsenic render it fusible, and may afterwards be expelled by heat.

Rhodium unites readily with every metal which Dr. Wollaston, its discoverer, tried, except mercury. With gold or silver, the alloy is malleable, not oxidized by a high degree of heat, but becoming encrusted with a black oxide when slowly cooled. One sixth of it does not perceptibly alter the colour of gold, but renders it much less fusible. Neither the nitric, nor the nitro-muriatic acid acts on it in the state of alloy with gold silver, but, if it be fused with three parts of bismuth, lead or copper, the alloy is entirely soluble in a mixture of nitric, mixed with two parts of muriatic acid.

URANIUM.

Uranium is of a dark grey color on the surface, within, it is a pale brown. Its hardness is about 6. It is more difficult of fusion than manganese. It is little

known, and appears not to be obtained in a state of purity, as the specimens of different chemists have varied in specific gravity from 6.440 to 9.000.

Klaproth discovered uranium in a mineral called *peach-blend*, which is obtained in Saxony, and which had been usually considered as an ore of zinc or iron, or even tungsten; but Klaproth's analysis evinced that it was the sulphuret of uranium.

When exposed for some time to a red heat, in a close vessel, uranium suffers no change; but by means of nitric acid, it is converted into a yellow oxide. This oxide is soluble in diluted sulphuric acid gently heated, and affords prismatic crystals of a lemon colour. It is also soluble in nitromuriatic acid, and may be precipi tated by alkalies.

COBALT.

Cobalt is of a whitish colour, inclining to a bluish or steel grey. When pure, it is somewhat malleable while red hot, and is also attracted by the magnet. Its hardness is 8, and its specific gravity is usually about 7.811. It is brittle, and has a dull, close-grained fracture. It is not acted upon by water, but tarnishes in the air; it requires, for its fusion, a heat not inferior to that for cast-iron. It has never been volatilized.

Cobalt has been found native; but mostly in the state of an oxide, united with arsenic, sulphur, iron, &c. It is plentiful in the mines of Saxony; and is also abundantly obtained in the Mendip Hills, Somersetshire, England, and in a mine near Penzance, in Cornwall.

Arsenical cobalt is of a greyish colour, and becomes black by exposure to air. The sulphurous ore of cobalt resembles the grey silver ore in its texture.

When the oxide of cobalt has been freed from arsenic and sulphur, which is done by pulverizing it, washing it, and then exposing it to a strong heat, it has an obscure grey colour, and is called *zaffre*. When zaffre is fused with three parts of pulverized flints, and one of potass, a beautiful blue glass is obtained. This glass, when

pulverized and washed, constitutes the *smalt* of commerce. Smalt is used to give the blue colour to writing paper, to starch, and linen. It also supplies a blue colour to the painters of earthenware and porcelain, and to enamellers.

Metallic cobalt may be obtained by fusing zaffre in a white heat, with three times its weight of black flux the cobalt, when reduced, sinks to the bottom of the cru cible. Or it may be obtained by fusing smalt with six or eight times its weight of soda.

Cobalt resists cupellation, nor will it amalgamate with mercury. It forms alloys with few of the metals: that with tin is of a light violet colour. The metals with which it combines most readily are arsenic and iron: these, when combined with it, are separated with difficulty. With iron, the alloy is hard, and not easily broken: with arsenic, it is brittle, fusible, and more easily oxidized than pure cobalt.

To dissolve cobalt in sulphuric acid, the acid must be concentrated, and distilled upon it almost to dryness. By washing the residuum, a portion of it dissolves in the water: this portion is sulphate of cobalt. The other part consists of oxide of cobalt. The cobalt may be precipitated from the water by lime and alkalies.

Nitric acid dissolves cobalt by the assistance of a gentle heat. Lime and alkalies precipitate it from its solution; and an excess of alkali dissolves the precipitate.

Muriatic acid does not dissolve cobalt without the assistance of heat. The nitro-muriatic acid dissolves cobalt more readily. This solution, much diluted, forms the much-admired sympathetic ink, which, when written with upon paper, is invisible; but, when the paper is warmed, the characters appear of a beautiful green, that gradually disappears as the paper cools; and the experiment may be repeated with the same result for an indefinite number of times.

Sulphur is not readily combined with cobalt by art; but alkaline sulphurets readily form the combination.

The phosphuret of cobalt may be formed by dropping

small pieces of phosphorus upon ignited cobalt in grains. It is white and brittle, and soon loses its lustre by exposure to the air: it is more fusible than cobalt.

MOLYBDENUM.

The ore containing molybdenum has almost the appearance of plumbago, and therefore, though scaly and more shining, it was, before it was carefully analyzed, mistaken for that mineral. It is unctuous to the touch, soils the fingers, and makes whitish and brilliant traces upon paper, whereas the traces of plumbago are dull. It has never been perfectly reduced; when made into a paste with linseed oil, or any other suitable substance, the strongest fires only agglutinate it in brittle masses, consisting of small grains. These grains are of a whitish yellow colour, but their fracture is a whitish grey. Their specific gravity is at least 7.500.

The alloys of molybdenum have been little examined; those with silver, iron, and copper, are friable; those with lead and tin pulverulent and fusible.

Molybdenum, by a strong heat, is gradually converted into a whitish coloured oxide. Nitric acid, which has a rapid action upon it, converts it into a *white oxide*. This oxide has the properties of an acid, and is therefore called *molybdic acid*. It dissolves in 576 parts of water at a mean temperature. It decomposes the solutions of soap, and precipitates alkaline sulphurets.

The muriatic acid has no action upon molybdenum, but dissolves its acid, which is also done by the sulphuric. Heat should be employed with both these acids.

Scheele discovered, 1, that fixed alkali rendered molybdic acid more soluble in water; 2, that salt prevents the acid of molybdenum from volatilization by heat; 3, that molybdate of potass falls down by cooling, in small crystalline grains, and that it may likewise be separated from its solvent by sulphuric and muriatic acids.

Blue carmine is prepared by precipitating tin from its

solution in muriatic acid with the molybdate of potass. The muriatic acid unites with the alkali, and the molybdic with the tin, to form the blue precipitate.

MANGANESE.

A MINERAL, called the *soap of glass*, has been employed for time immemorial in the manufacture of glass, which it whitens and renders colourless. It is usually of a grey or blackish colour, and soils the fingers. This mineral is the oxide of a peculiar metal called *manganese*.

Metallic manganese is of a greyish white colour, brittle, though not easily broken, and devoid of malleability. When reduced to powder, it is attracted by the magnet. Its specific gravity is 6.990; its hardness is 8. It is more difficult of fusion than iron.

When manganese is exposed to the atmosphere, it soon tarnishes, and becomes at last black and friable; heat accelerates this change; which produces the substance called *black oxide of manganese*. It is this oxide of the metal which is usually employed in the arts, and in which state manganese is generally found. The counties of Somerset and Devon supply large quantities of it, and in the vicinity of Aberdeen, a mine of it has been lately discovered, which furnishes twenty tons per week.

The black oxide of manganese contains 25 per cent. of oxygen; a portion of this oxygen is separated by heat, and, therefore, the oxide has recently become important, for the purpose of furnishing this gas. When manganese is employed in preparing oxymuriatic acid for medicine, the purest, such as that from Upton Pyne, should be used. That from Bristol and the Mendip Hills, generally contains lead.

Manganese is susceptible of three different degrees of oxydizement, forming the white, the red, and the black oxides of manganese. An oxide containing still more oxygen is asserted to be of a dark green.

Metallic manganese may be obtained, by mixing the black oxide into a ball with linseed oil; putting this ball

into a cavity made in a lump of charcoal, covering it with a layer of charcoal, enclosing the whole in a crucible, and subjecting it to an intense heat for one or two hours. Saline fluxes should be rejected for reducing this mineral, because it has so strong a disposition to vitrify, that it would be suspended in a flux of that kind.

Manganese unites by fusion with all the metals except mercury. With copper and iron it appears to combine the most readily; but none of its alloys are used in the arts, or known to be valuable.

The sulphuric acid attacks manganese, and produces hydrogen gas; the solution goes on more slowly than that of iron in the same acid; it is colourless. Sulphuric acid extricates from the oxide of manganese, a large quantity of oxygen gas.

The oxide of manganese is dissolved by nitric acid; muriatic acid, digested upon it, seizes its oxygen, and passes in vapour through the water. This vapour is oxymuriatic acid.

The oxide of manganese combines with the alkalies. It also combines with sulphur, which the metal does not.

Manganese at a red heat combines with phosphorus. The phosphuret is of a white colour, brittle, granulated, disposed to crystallize, not altered by exposure to the air, and more fusible than manganese.

TANTALIUM.

From a fossil called *tantalite*, and another called *ytro-tantalite*, Ekeberg extracted by means of the fixed alkalies, a white powder, which he ascertained to be the oxide of a peculiar metal. To this metal he gave the name of *tantalium*.

When the oxide of tantalium above mentioned is powerfully heated with charcoal, a button of metal is obtained, with a metallic lustre externally, but internally black and without brilliancy. Its hardness is 7; its specific gravity, 6.5. The acids will reduce it again to

the state of white oxide, but they will not dissolve it The oxide is not changed by a red heat. Caustic fixed alkali is the only re-agent which has any action upon it.

TITANIUM.

Titanium is of a brownish red colour, almost like copper. Its lustre is considerable, it is brittle, and very difficult of fusion. Its specific gravity is 4.18; its hardness 9.

Titanium is obtained from a mineral, plentiful in Hungary, called *red schorl*, which is its native red oxide; and from another mineral obtained in Cornwall, called *manacanite*.

Vanquelin obtained metallic titanium from its native red oxide, by mixing together 100 parts of this oxide with 50 of calcined borax, and 50 of charcoal, formed into a paste with oil; and exposed the whole to the heat of a forge raised to 166° of Wedgwood.

This metal is acted upon by the principal acids, except the nitric, and forms salts with them. It also combines with phosphorus. The phosphuret is of a pale white colour, brittle, granular, and infusible by the blow-pipe

The attempts to alloy titanium have not succeeded.

CHROMIUM.

Chromium is of a whitish colour, inclining to grey; it is very brittle; its fracture presents a radiated appearance, needles crossing in different directions, with interstices between them. It is difficult of fusion, resisting the heat of the blow-pipe.

Chromium was discovered by Vanquelin, in analyzing a beautiful mineral called *red lead of Siberia*. The mineral is a chromate of lead, in which chromium exists in the state of an acid. Its colour is a fine aurora red, with considerable lustre. Chromium has also been found united with iron, forming chromate of iron; it also exists in some gems, of which it appears to constitute the col-

ouring principle. In the emerald it exists in a state of green oxide, and the spiral ruby contains it in the state of an acid.

Vanquelin extracted this metal from the red-lead ore, by adding to it muriatic acid, which combines with the oxide of lead, and forms a compound that is precipitated, the chromic acid remaining in solution. To abstract a little muriatic acid combined with it, oxide of silver is cautiously added, and the pure chromic acid, being decanted from the precipitate of muriate of silver, and evaporated, is exposed to a very strong heat, excited by a forge, in a crucible of charcoal, placed within another of porcelain. It is thus reduced to the metallic state.

Sulphuric acid decomposes the red-lead ore; but it is difficult to separate the products. Nitric acid does not decompose this ore.

Chromic acid is very soluble in water: it is of an orange-red colour, with a pungent metallic taste. By evaporation, it affords crystals, in long slender prisms, of a ruby-red colour. This acid combines with the alkalies, earths, and metallic oxides, and the neutral salts which it forms with them are called chromates.

The combinations of this acid with metallic oxides are in general possessed of very beautiful colours, and are well adapted to the purposes of painting. That with oxide of lead is an orange-yellow, of various shades; that with mercury, a vermilion-red; with silver, a carmine-red; with zinc and bismuth, the colours are yellow; with copper, cobalt, and antimony, they are dull.

The term chromium is derived from a Greek word signifying colour, and is applied to this metal on account of the diversity of colours which its compounds form.

The specific gravity of chromium, and the four following metals, is uncertain.

COLUMBIUM.

A MINERAL in the British Museum, sent to Sir Hans Sloane, with some iron, from Massachusetts, upon being examined by Hatchett, was found to contain a new metallic substance, to which that eminent chemist has given the name of *columbium.*

The ore of columbium has never been perfectly reduced, but it affords an acid, called the columbic acid, which differs from all other bodies. The alkalies throw it down from its acid solutions, in white flakes. Prussiate of potass changes the blue colour to an olive green, and a precipitate of the same colour is gradually formed. Tincture of galls produces a deep orange coloured precipitate. Zinc occasions a white precipitate. The fixed alkalies readily combine with the columbic acid. It is insoluble and unalterable with regard to colour by the nitric acid.

CERIUM.

CERIUM is another newly discovered metal, which exists in a mineral called *cerite.* Cerite is semi-transparent, generally of a reddish colour, though occasionally yellowish. Some specimens are hard enough to scratch glass, and to strike fire with steel. To obtain the oxide of cerium, this mineral is pulverized, calcined, and dissolved in nitro-muriatic acid. The filtered solution, being neutralized with potass, is to be precipitated by nitrate of potass, and the precipitate, well washed, and afterwards calcined, is oxide of cerium. This oxide is susceptible of two degrees of oxidation; in the first it is white, and this by calcination becomes of a fallow red.

The white oxide of cerium, mixed with a large proportion of borax, fuses into a transparent globule; but in attempts to obtain the metallic cerium, the quantity operated upon has always been so far dissipated, that the sensible properties of the metal are unknown.

IRIDIUM.

In a black powder, left after dissolving crude platina, Tennant discovered two new metals, to one of which, he gave the name of *iridium*. To analyze this powder, it was mixed with pure dry soda, and kept at a red heat for some time, in a silver crucible. The alkali was then separated by solution in water, and the undissolved part of the powder was digested with muriatic acid, with which a solution, at first of a dark blue, was obtained; it afterwards became of a dusky olive-green, and at last, of a deep red. This acid solution contains two metals, but chiefly iridium. By its evaporation, may be obtained an imperfectly-crystallized mass, which, dissolved in water, gives, by evaporation, distinct octahedral crystals. These crystals, dissolved in water, produce a deep red solution, inclining to orange. By exposure to heat, the acid may be expelled; but the iridium thus produced has never been fused, except by a powerful galvanic battery. Its oxide, when obtained as above stated, is white: it neither combines with sulphur nor arsenic. Lead unites with it easily, but is separated by cupellation, leaving the iridium on the cupel, in the form of a coarse black powder. Copper and silver form with it malleable alloys; but the iridium appears to be diffused through the silver only in the state of a fine powder. Gold remains malleable, although alloyed with a considerable portion of it; and is not separated from it either by cupellation or quartation.

OSMIUM.

The metal found along with iridium, in the black powder left after dissolving platina, is called *osmium*.

The oxide of osmium may be obtained by distilling with nitre the black powder above-mentioned: at a low red heat, an apparently oily fluid sublimes into the neck of the retort, which, on cooling, concretes into a solid, colourless, semi-transparent mass. This, being dissolved

in water, forms a concentrated solution of oxide of osmium. This solution indelibly stains the skin of a deep red or black. Infusion of galls renders the solution at first purple, but in a little time, it becomes of a deep vivid blue. If mercury be agitated with the solution, it forms with the osmium a perfect amalgam. Part of the mercury may be separated by squeezing it through leather, and the rest by distillation, which will leave the osmium pure, in the state of a black powder. This powder has never been fused. It forms malleable alloys with copper and gold.

OF ACIDS.

Acids possess most or all of the following properties 1. They excite the sensation called *sourness* or *acidity* 2. They change the blue, green, and purple juices of vegetables to red. 3. They combine with alkalies, earths and metallic oxides; with which they form compounds called *salts.* 4. They combine with water in all pro portions.

Most of the acids have been proved to contain oxygen as a component part; and are more or less strong in proportion as they are combined with more or less oxygen They are not all, however, capable of combining with more than one dose or proportion of oxygen: a few are capable of combining with two doses of oxygen, and a still smaller number with three. No acid has been obtained by itself in combination with a fourth proportion of oxygen. These differences it becomes necessary to distinguish; and the distinction is made in the following manner.

When any body contains the smallest portion of oxygen, which converts it into an acid, the name of the base or radical of the acid is terminated by *ous;* thus, we have the *sulphurous* acid. The next degree of oxygenisement is expressed by the termination *ic;* thus, we say, *sulphuric* acid. The third degree is expressed by the addition of the word *oxygenized,* or its contraction,

oxy; thus, we have the *oxymuriatic* acid. A fourth degree of oxygenizement may be expressed by placing the term *hyper* before that of *oxy;* thus, we have *hyper oxymuriatic* acid. There is only one instance of this last mode of expression being necessary, and that instance only refers to the acid as it is supposed to exist in combination with another body.

ACERIC ACID.

A PECULIAR acid, said to exist in the juice of the maple. It is decomposed by heat, like the other vegetable acids.

ACETIC ACID.

ACETIC acid may be obtained from crystallized acetate of copper, which must be reduced to powder, and distilled. A fluid, possessing little acidity, first rises, and afterwards, a powerful acid. This acid has a greenish hue when first prepared, because a small part of the oxide of copper comes over with it; but it may be obtained, perfectly colourless, by distilling it with a gentle heat. It may also be prepared, with more certainty as to its freedom from copper, by distilling acetate of soda or acetate of potass, with half its weight of sulphuric acid.

Acetic acid is sold under the name of radical vinegar. It is colourless like water: its smell is extremely pungent, and its taste acrid. When applied to the skin, it reddens and corrodes it. It is extremely volatile, wholly evaporating on exposure to the air: and, when heated in the open air, it takes fire readily. At 50°, it freezes. It unites with water in any proportion; and on mixture with it, heat is evolved. It dissolves camphor; and, with the addition of essential oils, forms the *aromatic vinegar.*

Acetic acid is used for smelling at; crystals of sulphate of potass being put into a bottle, and moistened with it for that purpose. This mixture is called *volatile salt of*

vinegar. A few drops of sulphuric acid, added to a phial of the acetate of potass, make a strong smelling bottle by the evolutions of the acetic acid.

Acetic acid may be advantageously employed to separate manganese from iron. When both metals are dissolved in this acid, and the solution is evaporated to dryness, the acid adheres to the manganese, but abandons the iron. Water will then dissolve the acetate of manganese from the oxide of iron. Two or three evaporations and solutions are sufficient to remove the whole of its iron.

Acetic acid consists of oxygen, hydrogen, and carbon, but the proportions of its component parts have not been clearly proved; with various bases, it forms the salts called acetates.

BENZOIC ACID.

This acid is obtained from the resin called *benzoin* or *benjamin*, which is brought from the East Indies. By a gentle heat the resin is sublimed, and condenses in the form of long needles, or straight filaments of a white colour, crossing each other in all directions. These are what are sold under the name of *flowers of benjamin*, and consist of the acid in question. When pure, they are of a brilliant white, have an aromatic odour, are entirely soluble in alcohol, but the addition of water causes a precipitate. Hot water dissolves them copiously, but cold water scarcely at all. They are not altered by the air; their taste is acrid and bitter. They form a kind of paste if rubbed in a mortar.

The purest benzoic acid may be obtained in the humid way, by boiling the resin with carbonate of soda, and adding diluted sulphuric acid to the filtered decoction as long as it produces any precipitation. The precipitate is the benzoic acid.

Benzoic acid is so inflammable, that it burns with a clear yellow flame, without the assistance of a wick. The mineral acids dissolve it, but it separates from them without alteration, by the addition of water. It dissolves

in oils, and melted tallow. It unites with earthy and alkaline bases, forming the salts called benzoates.

AMNIOTIC ACID.

A PECULIAR acid found in the liquor of the amnois of the cow. It exists in the form of a white pulverulent powder. It is slightly acid to the taste, but sensibly reddens vegetable blues. It is with difficulty soluble in cold, but readily soluble in boiling water, and in alcohol. When exposed to a strong heat, it exhales an odour of ammonia and of prussic acid. Assisted by heat, it decomposes carbonate of potassa, soda, and ammonia. It produces no change in the solutions of silver, lead, or mercury, in nitric acid. Amniotic acid may be obtained by evaporating the liquor of the amnois of the cow to a fourth part, and suffering it to cool; crystals of amniotic acid will be obtained in considerable quantity. Whether this acid exists in the liquor of the amnois of other animals, is not yet known.

ARSENIOUS ACID.

THIS is nothing more than the white oxide of arsenic sold from the stores, without any preparation. It has a weakly acid taste, and sensibly reddens the tincture of cabbage and litmus, and most other vegetable blues; the syrup of violets, which it turns green, is an exception. If thrown on burning coals, or a red-hot iron, it is volatilized in the form of a white vapour, which emits the smell of garlic. By a strong heat it is vitrified into a transparent glass. It only contains about seven per cent. of oxygen.

Arsenious acid is soluble in 15 times its weight of boiling water, but requires for its solution eighty times its weight of cold water. The solution crystallizes best by slow evaporation; it is very acrid; it unites with the earthy bases, decomposes the alkaline sulphurets, and forms with them a yellow precipitate, in which the arsenic approaches to the metallic state.

The combinations of arsenious acid with different bases re called *arsenites.*

BORACIC ACID.

Boracic acid is procured from the salt called borax, in the following manner: the borax is dissolved in hot water, and the solution filtered; sulphuric acid is added very gradually to the solution, till it has a sensibly acid taste; being then left to cool, a number of small, shining, laminated crystals form in it; these crystals are the boracic acid; they are to be washed with cold water, and dried upon brown paper.

The crystals of boracic acid are thin irregular hexagons, of a silvery whiteness. They are soft and unctuous to the touch, almost like spermaceti. They have no smell, but a bitterish taste, with a slight degree of acidity; and they are unalterable in the air. When mixed with spirit of wine, they cause it to burn with a green flame. When sulphuric acid is poured upon them, a transient odour of musk is perceived.

Boracic acid, when exposed to a violent fire, is converted into a transparent glass; this glass is soluble in water, and the acid is again produced from evaporation.

It is much employed in analyzing minerals, as it brings almost all the stones into solution.

BUTYRIC ACID.

We owe the discovery of this acid to M. Chevreul. Butter, he says, is composed of two fat bodies, analogous to those of hogs' lard, of a colouring principle, and a remarkably odorous one, to which it owes the properties that distinguish it from the fats, properly so called. This principle, which he has called butyric acid, forms well characterized salts with barytes, strontian, lime, the oxides of copper, lead, &c.; 100 parts of it neutralize a quantity of base which contains 10 of oxygen. M. Chevreul has not explained his method of separating this acid from the other constituents of butter.

CAMPHORIC ACID.

Camphor is a concrete essential oil, of a strong taste and smell; it is extracted by sublimation from a species of laurel in the East Indies, and has a crystalline form. It is so volatile, that it cannot be melted in open vessels, and so imflammable, that it burns even on the surface of water. Kosegarten, by distilling nitric acid eight times successively from this substance, obtained an acid in crystals, which is called *camphoric acid.*

Camphoric acid is in snow-white crystals, which effloresce in the air. It has a slightly acid, bitter taste, and a smell like saffron. It reddens vegetable blues. It requires 200 times its weight of cold water to dissolve it; but boiling water takes up one-twelfth. If thrown upon burning coals, it is entirely dissipated in a thick aromatic smoke. With a gentle heat it melts and is sublimed. It is soluble in alcohol, and not precipitated from it by the addition of water, a property which distinguishes it from the benzoic acid. It does not precipitate lime from lime-water.

The mineral acids dissolve camphoric acid entirely, it is also dissolved by the fixed and volatile oils. It unites readily with the earths and alkalies, forming the salts called *camphorates.*

CARBONIC ACID.

Carbonic acid gas is the result of the combustion of carbon. Every 100 parts of it, according to Tennant, contain 18 parts of carbon and 82 of oxygen. Its weight is to atmospheric air as 1500 to 1000. It has no smell; is invisible and elastic, like common air, but extinguishes flame, and is totally unfit for respiration.

Carbonic acid is contained in the air to the amount of about one part in the thousand. It is absorbed by water if agitated, or long in contact with it. Strong pressure will cause the water to absorb three times its bulk of this gas, which imparts to it a taste agreeably acidulous

and causes it to have a sparkling lustre when poured from one vessel to another. The Pyrmont, Spa, and Seltzer waters, are neutral combinations of carbonic acid with water, and they can be imitated by art with the greatest precision.

The specific gravity of water saturated with carbonic acid is 1.0015. If water containing carbonic acid be frozen, the whole of this gas separates in freezing, and, therefore, ice is never found to contain any. A boiling heat also produces this separation.

Carbonic acid, from its gravity, may be poured from one vessel to another, but if a portion of it be left in an open vessel, for any length of time, it will be found to have escaped; the air having an attraction for it, gradually absorbs it, and will even abstract it from water.

Carbonic acid exists in incalculable quantities, combined with other substances. Marble, limestone, and chalk consist of it in combination with lime: it forms about one-third of their weight, and may be disengaged from any of these substances, by means of an acid, or considerable heat. The former means is generally more convenient, when a quantity is required for the purpose of experiment. The sulphuric acid, diluted with about six times its weight of water, is poured upon the marble, chalk, or limestone, previously reduced to a powder. An effervescence immediately ensues: this is occasioned by the extrication of carbonic acid gas, which must be collected by means of the pneumatic apparatus. The mercurial trough should be used, if the gas is not intended for immediate use.

Alcohol, and spirit of turpentine, absorb double their weight of carbonic acid gas; olive oil, its own bulk. Ether mixes with it in the state of gas.

Carbonic acid enters into combination with alkalies, alkaline earths, alumine, zircon, and metallic oxides, with which it forms salts called *carbonates*.

Water, impregnated with carbonic acid, and applied to the roots of plants, is highly favourable to vegetation; but, if this gas be applied to the leaves, as an atmosphere, it is injurious.

CASEIC ACID.

The name given by Proust to an acid formed in cheeses, to which he ascribes their flavour.

CHLORIC ACID.

This acid was first eliminated from salts containing it by Gay Lussac, and described by him, in his admirable memoir on iodine. When a current of chlorine is passed for some time through a solution of barytic earth, in warm water, a substance called hyper-oxymuriate of barytes, by its first discoverer, Chenevix, is formed, as well as some common muriate. The latter is separated, by boiling phosphate of silver in the compound solution. The former may then be obtained by evaporation, in fine rhomboidal prisms. Into a diluted solution of this salt, Gay Lussac poured weak sulphuric acid. Though he added only a few drops of acid, not nearly enough to saturate the barytes, the liquid became sensibly acid, and not a bubble of oxygen escaped. By continuing to add sulphuric acid with caution, he succeeded in obtaining an acid liquid, entirely free from sulphuric acid and barytes, and not precipitating nitrate of silver. It was chloric acid dissolved in water.

This acid has no sensible smell. Its solution in water is perfectly colourless. Its taste is very acid, and it reddens litmus without destroying the colour. It produces no alteration on solution of indigo in sulphuric acid. Light does not decompose it. It may be concentrated by a gentle heat, without undergoing decomposition, or without evaporating. It was kept a long time exposed to the air without sensible diminution of its quantity. When concentrated it has something of an oily consistency. When exposed to heat, it is partly decomposed into oxygen and chlorine, and partly volatilized without alteration. Muriatic acid decomposes it in the same way, at the common temperature. Sulphurous acid, and sulphuretted hydrogen, have the same property; but

nitric acid produces no change upon it. Combined with ammonia, it forms a fulminating salt. It does not precipitate any metallic solution. It readily dissolves zinc, disengaging hydrogen; but it acts slowly on mercury. It cannot be obtained in the gaseous state. Its taste is not only acid but astringent, and its colour, when concentrated, is somewhat pungent.

Chloric acid combines with the bases, and forms the *chlorates*, a set of salts formerly known by the name of *hyper-oxygenated muriates*.

CHLORIODIC ACID.

Sir H. Davy formed it, by admitting chlorine in excess to known quantities of iodine, in vessels exhausted of air, and repeatedly heating the sublimate. Operating in this way, he found that iodine absorbs less than one-third of its weight of chlorine.

Chloriodic acid, a very volatile substance, formed by the sublimation of iodine in a great excess of chlorine, is of a bright yellow colour; when fused it becomes of a deep orange, and when rendered elastic, it forms a deep orange coloured gas. It is capable of combining with much iodine when they are heated together; its colour becomes, in consequence, deeper, and the chloriodic acid and the iodine rise together in the elastic state. The solution of the chloriodic acid in water, likewise dissolves large quantities of iodine, so that it is possible to obtain a fluid containing very different proportions of iodine and chlorine.

When two bodies so similar in their characters, and in the compounds they form, as iodine and chlorine, act upon substances at the same time, it is difficult, Sir H. Davy observes, to form a judgment of the different parts they play in the new chemical arrangement produced. It appears most probable, that the acid property of the chloriodic compound depends upon the combination of the two bodies; and its action upon solutions of the alkalies and the earths may be easily explained, when it is con-

sidered that chlorine has a greater tendency than iodine to form double compounds with the metals, that iodine has a greater tendency than chlorine to form triple compounds with oxygen and the metals.

A triple compound of this kind with sodium may exist in sea-water, and would be separated with the first crystals that are formed by its evaporation. Hence, it may exist in common salt. Sir H. Davy ascertained by feeding birds with bread soaked with water, holding some of it in solution, that it is not poisonous like iodine itself.

CHROMIC ACID.

This acid is furnished by the mineral called the red lead ore of Siberia, which is a chromate of lead, and from which chromium is obtained. It also exists in the chromate of iron, which is more common than the former mineral, and in France is even abundant.

The acid is extracted from the real lead ore of Siberia, by boiling 100 parts of this mineral, with 300 of carbonate of potass, and 400 of water, and separating the alkali by means of weak nitric acid. It is an orange coloured powder, which has an acrid, metallic taste, is soluble in water, and crystallizable. If exposed to the action of light and heat, this powder loses oxygen and its acid properties, and is converted into the green oxide of chromium.

If the muriatic acid be distilled upon the chromic acid, it is oxygenized, and if simply mixed with the chromic acid, the same effect takes place, for it acquires the property of dissolving gold. This arises from the readiness with which chromic acid parts with its oxygen.

Chromic acid unites readily with alkalies. It also unites with borax, glass, and phosphoric acid, to which it communicates an emerald green colour.

CITRIC ACID.

The citric acid is found in the juice of lemons, oranges, unripe grapes, and some other fruits. It is extremely

acid to the taste, crystallizable, and very soluble in water: cold water dissolves rather more than its own weight of it, and hot water double its weight. The solution undergoes a spontaneous decomposition by long keeping.

If lemon juice be exposed in an open vessel, it deposits a quantity of mucilage, from which it may be separated by decantation and filteration. If the juice thus purified, be exposed to a freezing temperature, and the ice formed in it, which consists only of its aqueous particles, be removed as it is formed, the lemon juice will be obtained in a state of high concentration. Its quantity will be only about one-eighth of what it was at first, but its strength will be eight times greater. It may be kept for use, or may be made into dry lemonade, by adding six times its weight of fine loaf-sugar in powder.

The lemon juice, prepared as above, is not pure citric acid, but it retains a flavour which renders it better for domestic use than if it were pure. To prepare pure citric acid, Scheele saturated lemon-juice with lime, edulcorated the precipitate, which consisted of citric acid and lime, separated the lime from it by diluted sulphuric acid, cleared it from the sulphate of lime by repeated filterations and evaporations; then evaporated it to the consistence of a syrup, and set it in a cool place: a quantity of crystals formed which were pure citric acid. Like the oxalic acid, it possesses the property of speedily dissolving the oxides of iron. The dyers make use of it, for no other acid can be employed with so much success in enlivening the colours given by saffron: it appears also that it will form with granitin, a liquor which with cochineal, produces a scarlet colour superior to the usual dye, especially with silk and morocco leather. Citric acid whitens and hardens tallow, but as tartaric acid acts nearly as well in this respect, and is considerably cheaper, it is seldom made use of for this purpose.

Citric acid oxidizes iron, zinc, and tin. It does not act upon gold, silver, platina, mercury, bismuth, antimony or arsenic.

The combinations of the citric acid with the different bases, are called citrates.

COLUMBIC ACID

The experiments of Hatchett have proved that a peculiar mineral, found in Massachusetts, deposited in the British Museum, consisted of one part of oxide of iron and somewhat more than three of a white coloured substance, possessing the properties of an acid. Its basis was metallic. Hence, he named this columbium, and the acid, the columbic. Dr. Wollaston, by very exact analytical comparisons, proved that the acid of Hatchett was the oxide of the metal lately discovered in Sweden by Ekeberg, in the mineral ytrotantalite, and thence called tantalum. Dr. Wollaston's method of separating the acid from the mineral is peculiarly elegant. One part of tantalite, five parts of carbonate of potassa, and two parts of borax, are fused together in a platina crucible. The mass, after being softened in water, is acted on by muriatic acid. The iron and manganese dissolve, while the columbic acid remains at the bottom. It is in the form of a white powder, which is insoluble in nitric and sulphuric acids, but partially in muriatic. It forms, with barytes, an insoluble salt, of which the proportions, according to Berzelius, are 24.4 acid, and 9.70 barytes. By oxidizing a portion of the tantalum or columbium, Berzelius concludes the composition of the acid to be 100 metal, and 5.485 oxygen.

DELPHINIC ACID.

The name of an acid extracted from the oil of the dolphin. It resembles a volatile oil; has a light lemon colour, and a strong aromatic odour, analogous to that of rancid butter. Its taste is pungent, and its vapour has a sweetened taste of ether. It is slightly soluble in water, and very soluble in alcohol. The latter solution strongly reddens litmus. 100 parts of delphinic acid

neutralize a quantity of base which contains 9 of oxygen; whence, its prime equivalent appears to be 11.11.

ELLAGIC ACID.

So named by Braconnet, by reversing the word *galle*. The deposit, which forms in infusion of nut-galls left to itself, is not composed solely of gallic acid, and a matter which colours it. It contains, beside a little gallate and sulphate of lime, and a new acid, which was pointed out by Chevreuil, in 1815, an acid on which Braconnet made observations in 1818, and which he proposed to call acid *ellagic*, from the word *galle*, reversed. Probably this acid does not exist ready formed in nut-galls. It is insoluble; and, carrying down with it the greater part of the gallic acid, forms the yellowish crystalline deposit But boiling water removes the gallic acid from the ellagic; whence, the means of separating them one from another.

It has a pale yellow lemon colour, but no smell. Heat and light decompose it. Hydroeganic acid is then formed, and white ferro-prussiate of iron, which soon becomes blue. Its affinity for the bases enables it to displace acetic acid, without heat, from the acetates, and to form ferro-prussiates.

FLUORIC ACID.

This acid is contained in the mineral called *fluor* or *fusible spar*, which consists of fluoric acid and lime. If sulphuric acid be poured upon this spar in powder, the lime combines with it to form sulphate of lime, and the fluoric acid is expelled, and they may be collected by the pneumatic apparatus. The sulphuric acid should be well concentrated, and equal in weight to the fluor spar. A leaden retort must be used in the distillation, and only a gentle heat will be required. The gas should be received over mercury.

Fluoric acid gas is invisible and elastic like common air; it will not maintain combustion, and cannot be

breathed without causing death. It has the odour of muriatic acid, but is more corrosive, and when exposed to a moist atmosphere, it becomes cloudy.

Fluoric acid gas is heavier than common air. It corrodes the skin almost instantly. It combines rapidly with water, with which it forms liquid fluoric acid; as it dissolves silex, it cannot be prepared in glass vessels, nor kept in them, unless they be lined internally with wax or some similar coating. The acid combines with the silex of glass, and the silex passes over with it in the distillation. It is for this reason that it is usually kept as well as prepared in leaden or tin bottles. It is absorbed by alcohol and ether without altering their qualities: water impregnated with it must be cooled down to 23° before it will freeze.

The action of fluoric acid, upon all inflammable substances, is, in general, very feeble.

It will oxidize iron, zinc, copper, and arsenic; but has no action upon platina, gold, silver, lead, tin, antimony, cobalt, mercury.

It combines with alkalies, alkaline earths, alumine, and metallic oxides; and forms the salts called *fluates*.

Fluoric acid has been discovered in the enamel of the human teeth, and in ivory. Vanquelin also found it in topaz.

The only use to which fluoric acid has been applied, is that of etching upon glass. For this purpose, either the liquid fluoric acid may be employed, or the gas. If the former, the glass remains polished where the acid has corroded; but with the gas, the lines have the appearance as if the glass had been ground, and not polished. Landscapes, and other designs, properly executed upon glass, by means of this acid, have an elegant appearance. The process is the same as that for etching upon copper, except that so much care is not necessary in preparing the ground: bees'-wax alone will suffice.

GALLIC ACID.

This acid is found in the nut-galls, and generally in all astringent vegetables, though it exists independently of the astringent principle. The nut-gall is an excrescence produced on a species of oak, by the puncture of an insect.

The gallic acid may be obtained by various processes: the following method is proposed by Proust. Pour a solution of the muriate of tin into an infusion of nut-galls; a copious yellow precipitate is instantly formed, consisting of the tanning principle, combined with the oxide of tin. After diluting the liquor with a sufficient quantity of water to separate any portion of this precipitate which the acids might hold in solution, the precipitate is to be separated by filteration. The liquid contains gallic acid, muriatic acid, and muriate of tin. To separate the tin, a quantity of the sulphuretted hydrogen gas is to be mixed with the liquid. Sulphuret of oxide of tin is precipitated under the form of a brown powder. The liquid is then to be exposed for some days to the light, covered with paper, till the superfluous sulphuretted hydrogen gas exhales. After this, it is to be evaporated to the proper degree of concentration, and left to cool. Crystals of gallic acid are deposited: these are to be separated by filteration, and washed with cold water. The evaporation of the rest of the liquid is to be repeated, till all the gallic acid is obtained from it.

The gallic acid thus obtained has a very acid taste; it reddens vegetable blues, dissolves in $1\frac{1}{2}$ parts of boiling water, and 12 parts of cold water. Alcohol dissolves one-fourth of its weight in the cold, and its own weight, if assisted by heat.

Gallic acid thrown upon burning coals, inflames, and emits an aromatic odour, not very dissimilar to that of the benzoic acid. Its residuum is charcoal. It is decomposed by distillation. It has a great affinity for most of the metallic oxides, which it will take from the strongest acids. A solution of gold it renders green, and causes a

brown precipitate, which readily passes to the metallic state. On the nitric solution of silver, it has the same effect. Mercury, it precipitates of an orange-yellow; copper, brown; bismuth, of a lemon colour; lead, white; iron, purple, or black; for which reason, nut-galls are used to form writing-ink: they are also extensively used in dyeing. Platina, zinc, tin, cobalt, and manganese, it does not precipitate.

The combination of the gallic acid with the different bases, are called *gallates*.

HYDRIODIC ACID.

A gaseous acid in its insulated state. If 4 parts of iodine be mixed with one of phosphorus, in a small glass retort, applying a gentle heat, and adding a few drops of water from time to time, a gas comes over, which must be received in the mercurial bath. It is elastic and invisible, but has a smell somewhat similar to that of muriatic acid. Mercury after some time decomposes it, seizing its iodine, and leaving its hydrogen, equal to one half the original bulk, at liberty. Chlorine, on the other hand, unites to its hydrogen, and precipitates the iodine. From these experiments, it evidently consists of vapour of iodine and hydrogen, which combine in equal volumes, without change of their primitive bulk. Hydriodic acid is partly decomposed at a red heat, and the decomposition is complete if it be mixed with oxygen. Water is formed and iodine separated.

IODIC ACID.

When barytes water is made to act on iodine, a soluble hydriodate, and an insoluble iodate of barytes, are formed. On the latter well washed, pour sulphuric acid equivalent to the barytes present, diluted with twice its weight of water, and heat the mixture. The iodic acid quickly abandons a portion of its base, and combines with the water; but though even less than the

equivalent proportion of sulphuric acid has been used, a little of it will be found mixed with the liquid acid. If we endeavour to separate this portion, by adding barytes water, the two acids precipitate together.

LACCIC ACID.

This acid is obtained from *lacca*, the substance in which it exists. Dr. Sohn made a watery extract of powdered sticklac, and evaporated it to dryness. He digested alcohol on this extract, and evaporated the alcoholic extract to dryness. He then digested this mass in ether, and evaporated the ethereal solution; when he obtained a syrup mass of a light yellow colour, which was again dissolved in alcohol. On adding water to this solution, a little resin fell. A peculiar acid united to potassa and lime remains in the solution, which is obtained free, by forming with acetate of lead an insoluble laccate, and decomposing this with the equivalent quantity of sulphuric acid. Laccic acid crystallizes; it has a wine yellow colour, a sour taste, and is soluble as we have seen, in water, alcohol, and ether. It precipitates lead and mercury white, but it does not affect lime, barytes, or silver in their solutions. It throws down the salts of iron white. With lime, potassa, or soda, it forms deliquescent salts, soluble in alcohol.

LACTIC ACID.

This is the acid which appears in milk, that has become sour. To obtain it by Scheele's process, evaporate a quantity of sour whey to an eighth part, and then filter it; this separates the cheesy part. Saturate the liquid with lime-water, and the phosphate of lime precipitates. Filter again, and dilute the liquid with three times its own bulk of water; add to it oxalic acid, drop by drop, to precipitate the lime which has dissolved from the lime-water; then add a very small quantity of lime-water, to see whether too much oxalic acid has been added. If

there has, oxalate of lime immediately precipitates. Evaporate the solution to the consistence of honey, pour in a sufficient quantity of alcohol, and filter again; the acid passes through dissolved in the alcohol, but the sugar of milk, and every other substance, remains behind. Add to the solution a small quantity of water, and distil with a low heat; the alcohol passes over, and leaves behind the lactic acid dissolved in water.

Lactic acid is incapable of crystallizing; when evaporated to dryness, it deliquesces in the air. Its salts are called *lactates*.

LITHIC OR URIC ACID.

Scheele, in analyzing human calculi, found that a peculiar acid constituted a greater part of them all, and nearly the whole of some. It exists in human urine, from which it spontaneously separates in a few days in the form of red crystals with brilliant facets, the urine at the same time losing its colour and acid nature. It has neither taste nor smell, but reddens vegetable blues. It is soluble in 2000 times its weight of cold water. It is a composition of carbon, nitrogen, hydrogen, and oxygen.

This acid is found in the urine of the camel, and in those anthritic concretions commonly called chalk-stones.

MALIC ACID.

This acid is obtained by saturating the juice of apples with alkali, pouring in the acetous solution of lead, until it occasions no more precipitate. The precipitate is then to be edulcorated, and sulphuric acid poured on it, until the liquor has acquired a fresh acid taste, without any mixture of sweetness. The whole is then to be filtered, to separate the sulphate of lead. The filtered liquor is the malic acid, which is very pure, remains always in a fluid state, and cannot be rendered concrete.

MARGARITIC ACID.

When we immerse soap, made of pork-grease and potassa, in a large quantity of water, one part is dissolved, while the other part is precipitated in the form of several brilliant pellets. These are separated, dried, washed in a large quantity of water, and then dried on a filter: they are now dissolved in boiling alcohol, specific gravity 0.820; from which, as it cools, the pearly substance falls down pure. On acting on this with diluted muriatic acid, a substance of a peculiar kind, which Chevreuil, the discoverer, calls margarine, or margaritic acid, is separated. It must be well washed with water, dissolved in boiling alcohol; from which it is recovered, in the same crystalline form, when the solution cools.

Margaric acid is pearly white, and tasteless. Its smell is feeble, and a little similar to that of melted wax. Its specific gravity is inferior to that of water. It melts at 134° F., into a very limpid, colourless liquid, which crystallizes, on cooling, into brilliant white needles, of the finest white. It is insoluble in water, but very soluble in alcohol, specific gravity 0.800. Cold margaric acid has no action on the colour of litmus; but when heated so as to soften without melting, the blue was reddened. It combines with the salifiable bases, and forms neutral compounds. Two orders of margarites are formed, the *margarites*, and the *super-margarites;* the former being converted into the latter by pouring a large quantity of water on them. Other fats, besides that of the hog, yield this substance.

That of man is obtained under three different forms. 1. In very fine long needles, disposed in flat stars. 2. In very fine and very short needles, forming waved figures, like those of the margaric acid of carcases. 3. In very large brilliant crystals, disposed in stars, similar to the margaric acid of the hog. The margaric acids of man and the hog resemble each other; as do those of the ox and the sheep; and of the goose and the jaguar. The compounds with the bases, are real soaps. The solution in alcohol affords the transparent soaps of this country

MECONIC ACID.

This acid is a constituent of opium. It was discovered by Sertuerner, who procured it in the following way: After precipitating the *morphia*, from a solution of opium, by ammonia: he added to the residual fluid a solution of muriate of barytes. A precipitate is in this way formed, which is supposed to be a quadruple compound, of barytes, morphia extract, and the meconic acid. The extract is removed by alcohol, and the barytes by sulphuric acid; when the meconic acid is left, merely in combination with a portion of the morphia; from this it is purified by successive solutions and evaporations. The acid, when sublimed, forms long colourless needles; it has a strong affinity for the oxide of iron, so as to take it from the muriatic solutions, and form with it a cherry-red precipitate. It forms a crystallizable salt with lime, which is not decomposed by sulphuric acid, and what is curious, it seems to possess no particular power over the human body, when received into the stomach. The essential salt of opium, obtained in Derosne's original experiments, was probably the meconiate of morphia.

Robiquet has made a useful modification of the process for extracting meconic acid. He treats the opium with magnesia, to separate the morphia, while meconiate of magnesia is also formed. The magnesia is removed by adding muriate of barytes, and the barytes is afterwards separated by dilute sulphuric acid. A larger proportion of meconic acid is thus obtained.

MELASSIC ACID.

The acid present in melasses, which has been thought a peculiar acid by some, by others the acetic.

MELLITIC ACID.

Klaproth discovered in the mellilite, or honey stone, what he conceives to be a peculiar acid of the vegetable

kind, combined with alumina. This acid is easily obtained by reducing the stone to powder, and boiling it in about seventy times its weight of water; when the acid will dissolve, and may be separated from the alumina by filteration. By evaporating the solution, it may be obtained in the form of crystals. The following are its characters.

It crystallizes in fine needles or globules by the union of these, or small prisms. Its taste is at first a sweetish-sour, which leaves a bitterness behind. On a plate of hot metal it is easily decomposed, and dissipated in copious grey fumes, which affect not the smell, leaving behind a small quantity of ashes, that do not change either red or blue tincture of litmus. Neutralized by potassa, it crystallizes in groups of long prisms: by soda, in cubes, or triangular laminæ, sometimes in groups, sometimes single; and be ammonia, in beautiful prisms with six planes, which soon lose their transparency, and acquire a silver-white hue. If the metallic acid be dissolved in lime water, and a solution of calcined strontian or barytes be dropped into it, a white precipitate is thrown down, which is re-dissolved on adding muriatic acid. With a solution of acetate of barytes, it produces likewise a white precipitate, which nitric acid re-dissolves. With a solution of muriate of barytes, it produces no precipitate, or even cloud; but after standing some time, fine transparent needly crystals are deposited. The metallic acid produces no change in a solution of nitrate of silver. From a solution of nitrate of mercury, either hot or cold, it throws down a copious white precipitate, which an addition of nitric acid immediately re-dissolves. With nitrate of iron it gives an abundant precipitate of a dun yellow colour, which may be re-dissolved by muriatic acid. With a solution of acetate of lead, it produces an abundant precipitate, immediately re-dissolved on adding nitric acid. With acetate of copper, it gives a greyish-green precipitate; but it does not effect a solution of muriate of copper. Lime-water precipitated by it, is immediately re-dissolved on adding nitric acid.

MENISPERMIC ACID.

The seeds of *menispermune oculus*, being macerated for 24 hours, in 5 times their weight of water, first cold, and then boiling hot, yield an infusion, from which solution, sub-acetate of lead throws down a menispermate of lead. This is to be washed and drained, diffused through water, and decomposed by a current of sulphuretted hydrogen gas. The liquid thus freed from lead, is to be deprived of sulphuretted hydrogen by heat, and then forms solution of menispermic acid. By repeated evaporations and solutions in alcohol, it loses its bitter taste, and becomes a purer acid. It occasions no precipitate with lime-water; with nitrate of barytes it yields a grey precipitate; with nitrate of silver, a deep yellow; and with sulphate of magnesia, a copious precipitate.

MOLYBDIC ACID.

Molybdic acid is obtained from the ore or sulphuret of molybdenum, by distilling nitric acid off it repeatedly, till the sulphur and metal are both acidified, which is known by the conversion of the whole into a white mass. Hot water carries off the sulphuric acid, and leaves the molybdic acid in a state of purity.

Molybdic acid is a yellowish-white powder; it has an acrid but metallic taste. It is not altered in the air, and will bear a strong heat if the crucible be covered; but if the crucible be uncovered, the acid rises in the form of a white smoke. Its specific gravity is 3.75. It requires 570 times its weight of water to dissolve it. The solution has a sour taste, coagulates solutions of soap, and precipitates alkaline sulphurets. Paper dipped in this acid becomes of a beautiful blue colour in the sun.

The molybdic acid has not been applied to any use in the arts, though experiments have been made which indicate that it may become useful in dyeing. Its combinations with different bases are called molybdates.

MOLYBDENOUS ACID.

Molybdena is susceptible of four different combinations with oxygen; at the lowest it is in a state of black oxide; at the next it is blue; at the third it begins to assume acid properties, and is green. This is the *molybdenous acid.* The next dose of oxygen forms the yellowish white powder, which is the acid treated of in the last section.

MUCIC ACID.

This acid has been generally known by the name of *saccholactic*, because it was first obtained from sugar of milk; but as all the gums appear to afford it, and the principal acid in the sugar of milk is the oxalic, chemists, in general, now distinguish it by the name of mucic acid.

It was discovered by Scheele. Having poured twelve ounces of diluted nitric acid on four ounces of powdered sugar of milk, in a glass retort on a sand bath, the mixture became gradually hot, and at length effervesced violently, and continued to do so for a considerable time after the retort was taken from the fire. It is necessary therefore, to use a large retort, and not to bite the receiver too tight. The effervescence having nearly subsided, the retort was again placed on the sand heat, and the nitric acid distilled off, till the mass had acquired a yellowish colour. This exhibiting no crystals, eight ounces more of the same acid were added, and the distillation repeated, till the yellow colour of the fluid disappeared. As the fluid was inspissated by cooling, it was re-dissolved in eight ounces of water, and filtered. The filtered liquor held oxalic acid in solution, and seven drachms and a half of white powder remained on the filter. This powder was the acid under consideration.

If one part of gum be heated gently with two of nitric acid, till a small quantity of nitrous gas and carbonic acid is disengaged, the dissolved mass will deposit on cooling the mucic acid. According to Fourcroy and Vanquelin, different gums yield from 14 to 26 hundredths of this acid.

This pulverulent acid is soluble in about sixty parts of hot water, and by cooling, a fourth part separates in small shining scales, that grow white in the air. It decomposes the muriate of barytes, and both the nitrate and muriate of lime. It acts very little on the metals, but forms with their oxides salts scarcely soluble. It precipitates the nitrate of silver, lead, and mercury. With potassa it forms a salt soluble in eight parts of boiling water, and crystallizable by cooling. That of soda requires but five parts of water, and is equally crystallizable. Both these salts are still more soluble when the acid is in excess. That of ammonia is deprived of its base by heat. The salts of barytes, lime, and magnesia are nearly insoluble.

MURIATIC ACID.

Muriatic acid, so generally known under the name of *spirit of salt*, or *marine acid*, is a combination of oxy gen with an unknown base; for the acid has never been decomposed.

In its combinations it is very abundant in the mineral kingdom, particularly with soda, lime, and magnesia. Its combination with soda forms common salt, and the affinity of the two substances is such, that they are not separated by a heat which volatilizes salt. In obtaining this acid from muriate of soda, therefore, some substances must be used which will combine with the alkali. Sulphuric acid, or substances which contain it, such as clay, are generally used. Mix one part of sulphuric acid with two parts of dry muriate of soda, in a glass retort, apply a gentle heat, and use the mercurial pneumatic trough to collect the product which comes over. The product is muriatic acid in a state of gas. This gaseous acid is invisible, and elastic, like common air, but has about twice its specific gravity. It has a pungent, suffocating smell, and it is extremely caustic.

Muriatic acid gas absolves water with avidity. Water will combine with its weight of the gas, and the specific

gravity of the liquid muriatic acid thus obtained is 1.5 it is, however, not easily procured and preserved of a greater specitic gravity than 1.196.

Liquid muriatic acid is generally of a pale yellow colour, but this colour is attributed to the presence of some impurity; it preserves the smell of the gas, is very volatile, and gives out white fumes by exposure to the atmosphere.

It is capable, by the assistance of heat, of oxidizing iron, tin, lead, zinc, bismuth, cobalt, nickel, manganese, antimony, and arsenic. At a boiling heat, it oxidizes silver and copper. On gold, platina, mercury, tungsten, molybdenum, tellurium, and titanium, it has no action.

The proper solvent for gold and platina, is the nitro-muriatic acid, composed of one part of muriatic, and two of nitric acid.

Muriatic acid is the best test for silver. A single drop of it poured into a solution containing this metal will cause a copious precipitate.

Muriatic acid, combined with different bases, forms the salts called *muriates.*

This acid, in the state of gas, has a powerful effect in neutralizing putrid effluvia. Morveau, by pouring two pounds of sulphuric acid upon six pounds of common salt, and having the mixture on a common house furnace of live coal, completely destroyed the putrid exhalations which had caused the cathedral of Dijon to be deserted.

NITRIC ACID.

Nitric acid is formed by the chemical union of about 25 parts by weight of nitrogen, with 75 parts of oxygen. By mixing nitrogen and oxygen in these proportions, and passing a number of electrical shocks through the mixture, nitric acid is produced. In other words, the combustion of nitrogen produces nitric acid.

Nitric acid, combined with potass, form the salt called *nitrate of potass,* or saltpetre, and it is by the decomposition of this salt, that it may be procured. If three

parts of nitrate of potass, with one of sulphuric acid, be distilled, the nitric acid, mixed with a small proportion of nitrous, comes over. The nitrous acid may be expelled by a gentle heat. Nitric acid is clear and colourless, like water; it corrodes animal substances, and stains the human skin a permanent yellow. Its smell is remarkably pungent, and its taste strongly acid; in short, it eminently possesses all the properties enumerated as peculiar to acids. The action of light alone will, however, separate a part of its oxygen, and cause it to assume a yellow colour.

Nitric acid has a strong affinity for water, and has never been obtained except in combination with it. When concentrated, it attracts moisture from the atmosphere, but not so powerfully as the sulphuric acid. When mixed with water, it produces heat, but not in equal degree with the sulphuric acid. It boils at 248°. When concentrated to the utmost, its specific gravity is about 1.5. When diluted with water, it is sold under the name of *aquafortis:* even the double aquafortis of the stores sold is only about half the strength of nitric acid.

Nitric acid is easily decomposed, and it therefore constitutes a valuable agent to the chemist. It is capable of oxidizing all the metals, except gold and titanium; and even gold it appears to attack in a slight degree. If brought into contact with hydrogen at a slight temperature, a violent detonation is produced. If mixed with oils, it sets them on fire, and both the acid and the oil is decomposed. The oils should be free from water, but as this is rarely the case, the experiment is most certain of success if a little sulphuric acid be mixed with the nitric acid, as that acid will combine with the water. Oils deprived of water by boiling, inflame with nitric acid alone. In making these mixtures, the operator should keep himself at a distance from them, by using vessels with long handles.

Perfectly dry charcoal is also inflamed by nitric acid: with dry filings of iron the same effect takes place; and

also with zinc, and tin, if the acid be poured upon them in fusion.

The nitric acid, with the alkalies, alkaline earths, alumine, zircon, and the oxides of metals, form the salts called *nitrates*.

NITROUS ACID.

According to the principles of the new nomenclature, there is no acid strictly entitled to the appellation of nitrous acid: the acid which obtains this name is not the acid of nitre with a minimum of oxygen, but nitric acid, combined with different proportions of nitric oxide; of which an account will be found under the head of oxides.

Nitrous acid is more or less coloured, according to the quantity of nitric oxide with which it is impregnated. It parts with the gas very readily; which, when in quantity, passes off in vapours that assume a red colour on mixing with the atmosphere. On account of the extrication of these vapours, the acid is sometimes called fuming aquafortis. The addition of different portions of water causes nitrous acid to appear blue, green, yellow, &c.; but the vapours are always of the same red hue.

The general properties of nitrous acid are similar to those of the nitric; with different bases, it forms the salts called *nitrates*. These are not formed by the direct union of their component parts; but by exposing nitrates to a high temperature, which, separating a part of their oxygen, leaves them in the state of nitrates.

NITROLEUCIC ACID.

This acid is so named from its being obtained by the action of *nitric acid* on *leucine*. *Leucine* is capable of uniting to nitric acid, and forming a compound, which Braconnet has called the nitroleucic acid. When we dissolve leucine in nitric acid, and evaporate the solution to a certain point, it passes into a crystalline mass, without any disengagement of nitrous vapour, or of any

gaseous matter. If we press this mass between blotting-paper, and dissolve it in water, we shall obtain from this, by concentration, fine divergent, and nearly colourless needles. These constitute the new acid. It unites to the bases, forming salts which fuse on red-hot coals. The nitro-leucates of lime and magnesia are unalterable in the air.

NITRO-MURIATIC ACID.

Aqua regia. When nitric and muriatic acids are mixed, they become yellow, and acquire the power of readily dissolving gold, which neither of the acids possessed separately. This mixture evolves chlorine, a partial decomposition of both acids having taken place; and water, chlorine, and nitrous acid gas are thus produced: that is, the hydrogen of the muriatic acid abstracts oxygen from the nitric, to form water. The result must be chlorine and nitrous acid.

NITRO-SULPHURIC ACID.

A COMPOUND consisting of one part of nitre dissolved in about ten of sulphuric acid.

OLEIC ACID.

WHEN potassa and hogs' lard are saponified, the margarate of the alkali separates in the form of a pearly-looking solid, while the fluid fat remains in solution, combined with the potassa. When the alkali is separated by tartaric acid, the oily principle of fat is obtained, which Chevreuil purifies by saponifying it again, and again recovering it two or three times; by which means the whole of the margarine is separated. As this oil has the property of saturating bases, and forming neutral compounds, he has called it oleic acid.

OXALIC ACID.

The oxalic acid exists in the juice of the wood-sorrel, combined with potass. When prepared from this plant, it is sold under the name of *salt of lemons;* and is used as a substitute for the real juice of lemons. Sugar, and all other saccharine substances, contain the radical of the very same acid which wood-sorrel affords. It may be extracted from sugar in the following manner:

To six ounces of nitric acid, in a tubulated retort, to which a large receiver is luted, add, by degrees, one ounce of lump sugar, coarsely powdered. A gentle heat may be applied during the solution, and nitric oxide will be evolved in abundance. When the whole of the sugar is dissolved, distil off a part of the acid, till what remains in the retort has the consistence of a syrup, and this will form regular crystals, amounting to 58 parts from 100 of sugar. These crystals may be dissolved in water, re-crystallized, and dried on blotting-paper.

Honey, gum arabic, alcohol, the calculous concretions in the kidneys and bladders of animals, silk, wool, hair, and various other bodies, afford oxalic acid, by distillation with nitric acid. Berthollet observes, that the quantity of the acid afforded by vegetable matters is in proportion to their nutritive qualities.

The crystals of oxalic acid effloresce in dry air, but attract a little humidity if it be damp. They are soluble in one part of hot, and two parts of cold water; and are decomposed by a red heat. When dissolved in 3600 times their weight of water, the solution still reddens litmus-paper, and is perfectly acid to the taste.

The oxalic acid is a good test for lime, for which it has a greater affinity than any other acid. It forms with lime, an insoluble salt, not decomposable except by fire, and turning syrup of violets green.

Oxalic acid is capable of oxalizing lead, copper, iron, tin, bismuth, nickel, cobalt, zinc, and manganese.

The combination of oxalic acid with the alkalies and other bases, form the salts called oxalates.

Oxalic acid dissolved in water is employed by calico printers to destroy or lighten colours which are produced by iron. It is also used to remove iron moulds, and to take out spots of ink from furniture, and various other articles, which it does with the greatest facility. The crystals of oxalic acid much resemble those of Epsom salt which are much used as a purgative: several unfortunate accidents have happened through its having been taken by mistake, as the corrosive power of this acid is very great, when taken in so large a dose as Epsom salt.

OXYMURIATIC ACID.

If 84 parts of muriatic acid be combined with 16 of oxygen, they form *oxymuriatic acid.* This combination is usually formed by adding to one part of the black oxide of manganese, two parts of strong muriatic acid, and distilling the mixture with a gentle heat. The gas obtained is received over water, by means of pneumatic apparatus.

Oxymuriatic acid gas is tinged of a yellow colour by contact with atmospheric air; it supports flame, but cannot be breathed without the most injurious effects. Pelletier having attempted to respire it, the consequence was a consumption, which in a short time put a period to his life. If it happen to be accidentally inhaled, the vapour of volatile alkali, for which it has a strong affinity, is the best remedy. It does not readily unite with water; and at the temperature of freezing water it crystallizes.

Other acids become more intensely sour by an additional dose of oxygen, but the muriatic has this property diminished by the same addition. The taste of oxymuriatic acid is harsh and styptic, and instead of reddening vegetable colours, it changes them all to white, and their colours cannot be restored either by acids or alkalies. On this account, it has been extensively used in the process of bleaching. After having thus been employed upon a sufficient quantity of materials, it is

converted into common muriatic acid. It has, therefore, produced its effect by imparting oxygen.

As the oxymuriatic acid eradicates writing-ink, but nas no effect upon printing-ink, it may be conveniently used for whitening soiled books and prints; it removes all stains but those of an oily nature. An easy mode of preparing a quantity of it, consists in adding one ounce of the red oxide of lead to three ounces of muriatic. The red lead supplies the oxygen which oxygenizes the acid. This preparation should not be made till near the time against which it is wanted, and when made it should be kept in the dark, as it is deoxygenized by the light.

The nitromuriatic and oxymuriatic acids have the same appearance and odour, as well as the same effects, as solvents. It appears, therefore, that the nitric acid, when added to the muriatic, has only the effect of supplying it with oxygen.

Oxymuriatic acid oxidizes nearly all the metals without the assistance of heat. It decomposes the red sulphuret of mercury, which neither the sulphuric nor the nitric acid will accomplish. It may be combined with a great number of bases; the salts which it forms detonate with carbon and several metallic substances.

Hyper-oxymuriate of potass is made by introducing the oxymuriatic acid gas into a solution of potass; its crystals, as well as those of common muriate, being formed by evaporation in the dark. It gives a faint taste, with a sensation of coldness in the mouth; the crystals have somewhat of a silvery appearance, and emit light by attrition. It is decomposed by the action of light, parting with oxygen, and becoming simple muriate of potass. Heat also separates its oxygen in the form of gas; 100 grains of it will yield 75 cubic inches of oxygen gas.

When three parts of hyper-oxymuriate of potass, and one of sulphur, are triturated in a mortar, the mixture detonates violently. The same effect is produced when the mixture is struck with a hammer upon an anvil.

Phosphorus and hyper-oxymuriate of potass detonate with prodigious force.

Exotic seeds which could not be caused to germinate by ordinary means, have germinated after being steeped or a few days in weak oxymuriatic acid.

PHOSPHORIC ACID.

The purest phosphoric acid is obtained by the com bustion of phosphorus in oxygen gas. If no moisture be present, it is obtained in the form of white flocks, which are very light, and have a strongly acid taste. These flocks will attract moisture from the atmosphere, and become a fluid acid. This acid may be concentrated till its specific gravity exceeds that of the sulphuric acid; though strongly acrid, it is not corrosive, and has no smell.

Phosphoric acid may likewise be obtained by heating phosphorus with nitric or sulphuric acid; it remains in the retort, after these acids are driven over. Another mode of forming it, consists in exposing phosphorus for some weeks to the common temperature of the atmosphere, by which means it is gradually converted into a liquid acid. It is usually placed on the inclined side of a funnel, through which the liquid which is formed drops into a bottle placed beneath to receive it, and containing a little distilled water. The acid thus prepared, is called *phosphoric acid by deliquescence.*

The quantity of acid obtained from phosphorus, is generally about three times the weight of the phosphorus used.

If phosphoric acid be exposed to heat, it gradually becomes thick and glutinous; and if the heat be continued, it melts into a kind of glass, which is called the *glacial* acid of phosphorus, or glacial phosphoric acid. This glacial acid becomes liquid by exposure to the atmosphere.

Phosphoric acid, when perfectly dry, sublimes in close vessels, but the addition of water deprives it of this property. If mixed with charcoal, or other inflammable matter, and exposed to a strong heat, it parts with its oxygen, and is converted into phosphorus.

Phosphoric acid, assisted by heat, has some action upon silex, and will, therefore, decompose glass.

The salts of phosphorus are called *phosphates*. The phosphate of lime exists in bones, from which phosphorus is generally prepared. Whole mountains of phosphate of lime are said to exist in the province of Estremadura, in Spain.

PHOSPHOROUS ACID.

The spontaneous combustion of phosphorus at the temperature of the atmosphere, forms, in the first instance, *phosphorous acid*, which contains less oxygen than the phosphoric; but, as phosphorous acid acquires an additional quantity of oxygen from the atmosphere, it is speedily converted into the phosphoric.

Phosphorous acid is, therefore, very little known. It may, therefore, be decomposed by charcoal; but cannot be reduced to the glacial state. Its salts are called *phosphates*.

PRUSSIC ACID.

This acid exists, combined with iron, in the fine blue pigment, well known by the name of *Prussian blue*. It may be obtained as follows: mix four ounces of Prussian blue with two of red oxide of mercury, prepared by nitric acid, and boil them in twelve ounces, by weight, of water, till the whole becomes colourless; filter the liquor, and add to it one ounce of clean iron filings, and six or seven drachms of sulphuric acid: drain off, by distillation, about a fourth of the liquor, which will be prussic acid; though, as it is liable to be contaminated with a portion of sulphuric acid, to render it pure, it may be rectified by re-distilling it off carbonate of lime.

The prussic acid has a smell like that of peach blossoms. Its taste is at first sweetish, then acid and hot, and it excites coughing. It is very volatile, and capable of existing in an acid in the gaseous form.

The prussic acid combines with earths, alkalies, and

metallic oxides, forming the salts called *prussiates*. The prussiate of potash and iron, often called the prussian alkali, is one of the most important of these compounds, both for its utility as a test, and for making prussian blue. To form it, two parts of bullock's blood, and one of potash, are calcined by a moderate heat in a covered crucible, containing a hole in the lid. The calcination is to be discontinued when the matter ceases to afford a small blue flame. The residuum must be lixiviated with a small quantity of cold water. In this state, the prussiate of potass may be employed for making prussian blue, though not pure enough for the use of the chemist. Henry recommends it to be obtained by the following process from prussian blue, when required quite pure: To a solution of potass, deprived of its carbonic acid by quick-lime, and heated nearly to the boiling point, add by degrees powdered prussian blue, till its colour ceases to be discharged. Filter the liquor, wash the sediment with water, till it ceases to extract any thing, mix the washings together, and pour the mixture into an earthen dish in a sand-heat. When the solution has become hot, add a little diluted sulphuric acid, and continue the heat about an hour. A copious precipitate of prussian blue will be formed, which must be separated by filteration. Assay a small quantity of the filtered liquor in a wine-glass, with a little diluted sulphuric acid. If an abundant production of prussian blue still take place, the whole liquor must be exposed again to heat with a little diluted sulphuric acid, and this must be repeated as often as is necessary. Into the liquor thus far purified, pour a solution of sulphate of copper in four or six times its weight of warm water, as long as a reddish brown precipitate continues to appear. Wash the precipitate, which is a prussiate of copper, with repeated effusions of warm water; and when the water comes off colourless, lay the precipitate on a linen filter to drain, after which it may be dried on a chalk-stone. When the precipitate is dry, powder it, and add it by degrees to a solution of potass, which will take the prussic acid from the oxide of copper.

This prussiate of potass, however, will be contaminated by some portion of sulphate of potass, from part of which it may be freed by gentle evaporation, as the sulphate crystallizes first. To the remaining liquor, add a solution of barytes in warm water, as long as a white precipitate ensues, observing not to add more after its cessation. The solution of prussiate of potass will now be freed in a great measure from iron, and entirely from sulphate, and by gentle evaporation, will form, on cooling, beautiful crystals. These, dissolved in cold water, afford the purest prussian alkali that can be prepared. If pure barytes be not at hand, acetate of barytes may be used instead; as the acetate of potass formed, not being crystallizable, will remain in the mother-water.

Prussiates of soda and of ammonia may be prepared in a similar way to the prussiate of potass, above described.

PYROLIGNEOUS ACID.

In the destructive distillation of wood, an acid is obtained, which was formerly called *acid spirit of wood*, and since pyroligneous acid. Fourcroy and Vanquelin showed that this acid was merely the acetic contaminated with empyreumatic oil and bitumen.

Monge discovered, that this acid has the property of preventing the decomposition of animal substances. Mr. Wm. Dinsdale, of Field Cottage, Colchester, three years prior to the date of Monge's discovery, did propose to the Lord Commissioners of the Admiralty, to apply a pyroligneous acid, prepared out of the contact of iron vessels, which blacken it, to the purpose of preserving animal food, wherever their ships might go. As this application may in many places afford valuable anti-scorbutic articles of food, and thence might be eminently conducive to the health of seamen; it is to be hoped that Mr. Dinsdale's ingenious plan might be carried into effect, as far as is deemed necessary. It is sufficient to plunge meat for a few moments into this acid, even slightly empyreumatic, to preserve it as long as you

please. Putrefaction, it is said, not only stops but retrogrades. To the empyreumatic oil a part of this effect has been ascribed; and hence has been accounted for, the agency of smoke in the preservation of tongues, hams, herrings, &c. Dr. Jorg, of Leipsic, has entirely recovered several anatomical preparations from incipient corruption by pouring this acid over them. With the empyreumatic oil or tar he has smeared pieces of flesh already advanced in decay, and notwithstanding that the weather was hot, they soon became dry and sound. Mr. Ramsey has added the following facts in the 5th number of the Edinburgh Philosophical Journal. If fish be simply dipped in redistilled pyroligneous acid, of the specific gravity 1.012, and afterwards dried in the shade, they preserve perfectly well. On boiling herrings treated in this manner, they were very agreeable to the taste, and had nothing of the disagreeable empyreuma which those of his earlier experiments had, which were steeped for three hours in the acid. A number of very fine haddocks were cleaned, split, and slightly sprinkled with salt for six hours. After being drained, they were dipped for about three seconds in pyroligneous acid, then hung up in the shade for about six days. On being broiled, the fish were of an uncommon fine flavour, and delicately white. Beef treated in the same way, had the same flavour as the Hamburgh beef, and kept as well. Mr. Ramsey has since found, that his perfectly purified vinegar, specific gravity 1.034, being applied by a cloth or spunge to the surface of fresh meat, makes it keep sweet and sound for many days longer in summer, than it otherwise would. Immersion for a minute in his purified common vinegar, specific gravity 1.009, protects beef and fish from all taints in summer, provided they be hung up and dried in the shade. When by frequent use the pyroligneous acid has become impure, it may be clarified by beating up 20 gallons of it with a dozen of eggs in the usual manner, and heating the mixture in an iron boiler. Before boiling, the eggs coagulate, and bring the impurities to the surface of the boiler, and are of

course to be carefully skimmed off. The acid must be immediately withdrawn from the boiler, as it acts on iron.

This acid has long been prepared for the calico-printers. The following arrangement of apparatus has been found to answer very well. A series of cast-iron cylinders, about four feet diameter, and six feet long, are set in pairs, horizontally, in brick-work, so that the flame of one fire may play round both. Both ends project a little from the brick-work: one of them has a cast-iron plate well fitted, and firmly bolted to it, from the centre of which, an iron pipe, about six inches in diameter, proceeds, and enters, at a right angle, the main cooling-pipe. The diameter of this main pipe may be from 9 to 14 inches, according to the number of cylinders. The other end of the cylinder is called the mouth of the retort. This is closed by an iron plate, smeared round its edge with clay, and secured in its place by wedges. The charge of wood for such cylinders is about 8 cwt.

The hard woods, oak, ash, birch, and beech, are alone used; but fir does not answer. The heat is kept up during the day-time, and the furnace is allowed to cool during the night. Next morning, the door is opened, the charcoal is removed, and a new charge of wood is introduced. The average product of wood vinegar, or raw pyroligneous acid, is thirty-five gallons. It is much contaminated with tar, is of a deep brown colour, and has a specific gravity of 1.025; so that its weight is about 3 cwt.; but the residuary charcoal is found to weigh no more than one-fifth of the wood employed.

The raw pyroligneous is rectified by a second distillation in a copper-still, in the body of which, about 20 gallons of viscid tarry matter is left from every 100 of vinegar, and then passes over a transparent, but brown vinegar, having a considerable smell, and its specific gravity is 1.013. Its acid powers are superior to those of the best wine or malt vinegar, in the proportion of three to two.

RUCUMIC ACID.

An acid said to be peculiar to rhubarb, but not yet sufficiently examined.

ROSACIC ACID.

There is deposited from the urine of persons labouring under gout and inflammatory fevers, a sediment of a rose colour, occasionally in reddish crystals. It was at first discovered to be a peculiar acid by M. Proust, and afterwards examined by M. Vanquelin. This acid is solid, of a lively cinnabar hue, without smell, with a faint taste, but reddening litmus very sensibly. On burning coal it is decomposed into a pungent vapour, which has not the odour of burning animal matter. It is very soluble in water, and even softens in the air. It is soluble in alcohol. It forms soluble salts with potassa, soda, ammonia, barytes, strontites, and lime. It gives a slight rose-coloured precipitate, with acetate of lead. It also combines with lithic acid, forming so intimate a union, that the lithic acid in precipitating from urine, carries the other, through a deliquescent substance, down along with it. It is obtained pure by acting on the sediment of urine with alcohol.

SEBACIC ACID.

Subject to a considerable heat 7 or 8 pounds of hog's lard, in a stone-ware retort capable of holding double the quantity, and connect its beak by an adopter with a cooled receiver. The condensible products are chiefly fat, altered by the fire, mixed with a little acetic and sebacic acids. Treat this product with boiling water several times, agitating the liquor, allowing it to cool, and decanting each time. Pour at last into the watery liquid, solution of acetate of lead in excess. A white flocculent precipitate of sebate of lead will instantly fall, which must be collected on a filter, washed and dried. Put the

sebate of lead into a phial, and pour upon it its own weight of sulphuric acid, diluted with five or six times its own weight of water. Expose this phial to the heat of about 212°. The sulphuric acid combines with the oxide of lead, and sets the sebacid acid at liberty. Filter the whole while hot. As the liquid cools, the sebacid acid crystallizes, which must be washed, to free it from the adhering sulphuric acid. Let it then be dried at a gentle heat.

The sebacid acid is inodorous; its taste is slight, but it perceptibly reddens litmus paper; its specific gravity is above that of water, and its crystals are small white needles of little coherence. Exposed to heat, it melts like fat, is decomposed, and partially evaporated. The air has no effect upon it. It is much more soluble in hot than in cold water; hence boiling water saturated with it, assumes a nearly solid consistence on cooling. Alcohol dissolves it abundantly at the common temperature.

With the alkalies it forms soluble neutral salts: but if we pour into them concentrated solutions, sulphuric, nitric, or muriatic acids, the sebacic is immediately deposited in large quantity. It affords precipitates with the acetates and nitrates of lead, mercury, and silver.

Such is the account given by Thenard of this acid.

SELINIC ACID.

If selinium be heated to dryness, it forms, with nitric acid, a volatile and crystallizable compound, called selinic acid, which unites to some of the metallic oxides, producing salts called *seleniates.*

SORBIC ACID.

From *sorbus*, the mountain-ash, from the berries of which it is obtained. The acid of apples, called malic, may be obtained most conveniently, and in the greatest purity, from the berries of the mountain-ash, called *sorbus*, or *pyrus aucuparia;* and hence, the present name,

sorbic acid. This was supposed to be a new and peculiar acid by Donovan and Vanquelin, who wrote good dissertations upon it. But it now appears, that the sorbic and pure malic acids are identical.

Bruise the ripe berries in a mortar, and then squeeze them in a linen bag. They yield nearly half their weight of juice, of the specific gravity of 1.077. This viscid juice, by remaining for about a fortnight in a warm temperature, experiences the vinous fermentation, and would yield a portion of alcohol. By this change, it has become bright, clear, and passes easily through the filter, while the sorbic acid itself is not altered. Mix the clean juice with a filtered solution of acetate of lead, separate the precipitate on a filter, and wash it with cold water. A large quantity of boiling water is then to be poured upon the filter, and allowed to drain in glass jars. At the end of some hours, the solution deposits crystals of great lustre and beauty Wash these with cold water, dissolve them in boiling water, filter, and crystallize. Collect the new crystals, and boil them for half an hour in two or three times their weight of sulphuric acid, specific gravity of 1.090, supplying water as fast as it evaporates, and stirring the mixture diligently with a glass rod. The clear liquor is to be decanted into a tall, narrow glass jar, and, while still hot, a stream of sulphuretted hydrogen is to be passed through it. When the lead has been all thrown down in a sulphuret, the liquor is to be filtered, and then boiled in an open vessel, to dissipate the adhering sulphuretted hydrogen. It is now a solution of sorbic acid. When it is evaporated to the consistence of a syrup, it forms mamelated masses, of a crystalline structure. It still contains considerable water, and deliquesces when exposed to the air. Its solution is transparent, colourless, void of smell, but powerfully acid to the taste. Lime and barytes waters are not precipitated by solution of the sorbic acid, although the sorbate of lime is nearly insoluble. One of the most characteristic properties of this acid is the precipitate which it gives

with the acetate of lead, which is at first white and flocculent, but afterwards assumes a brilliant, crystalline appearance. With potassa, soda, and ammonia, it forms crystallizable salts, containing an excess of acid.

STANNIC ACID.

A NAME which has been given to the peroxide of tin, because it is soluble in alkalies.

SUCCINIC ACID.

THIS acid is obtained from amber, which is a brown, transparent, combustible substance, dug out of the earth, in some countries, and found upon the sea-coast, in others.

During the distillation of amber, the crystals of this acid attach themselves to the neck of the retort. They were formerly called *salt of amber.* When purified by repeated solution in hot water, filteration, and recrystallization, they are white, shining, triangular prisms. Their taste is slightly acid: they redden tincture of litmus, but have no effect on syrup of violets.

This acid obtains its name from *succinum*, the Latin name of amber. Its salts are called *succinates.*

SUBERIC ACID.

THIS acid exists in cork. It is obtained by distilling nitric acid of cork grated to powder, till the cork acquires the consistence of a wax, and no more red fumes appear. The residuum is placed in a sand-heat, and continually stirred, till white penetrating vapours appear. It is then removed from the sand-heat, and stirred till cold. Boiling water is poured upon the product; heat is applied till it liquifies, and it is then filtered. A sediment is deposited, which must be separated by the filter, and the fluid evaporated nearly to dryness. The mass thus obtained is the *suberic acid.* It may be further

purified by saturating it with potass, and precipitating it by means of an acid; or by boiling it along with char coal powder.

Suberic acid is not crystallizable; boiling water dissolves half its weight of it, but it is nearly insoluble in cold water. Its taste is acid, and slightly bitter. It reddens most vegetable blues, but has the peculiar property of changing the solution of indigo in sulphuric acid to a green.

It attracts moisture from the atmosphere, and exposure to light renders it brown. It has no action on gold or nickel, but oxidixes most of the other metals. With different bases, its salts are called *suberates*.

SULPHURIC ACID.

Sulphuric acid is the union of oxygen and sulphur, in which the proportion of sulphur is, according to Berthollet, 63.2, and that of oxygen 36.8.

Sulphuric acid is strongly corrosive and destitute of colour and smell. It may be rendered twice the weight of water, but its customary specific gravity seldom exceeds 1.8. When concentrated only to 1.7, it will freeze sooner than water, but not if either more or less concentrated. This was discovered by Keir. Sulphuric acid is so intensely acidulous, that though diluted with 7000 times its weight of water, its taste is still distinguishable.

Sulphuric acid was formerly procured by distillation from the salt which, previous to the adoption of the new nomenclature, was called *green vitriol;* on this account, and its having in some measure an oily consistence, it was called *oil of vitriol.* At present, it is furnished for the demand of trade, by burning sulphur in close chambers, with the addition of nitrate of potass to supply oxygen. The floor of the chamber is covered by a leaden cistern, containing water, by which the vapours of the sulphur are attracted and condensed. This process does not furnish the acid in a state of purity; but at least communicates to it some of the foreign substances lead and potass. It is purified by distillation.

Sulphuric acid speedily destroys the texture of animal and vegetable substances; it changes all vegetable blues to red, with the exception of indigo. It has a strong attraction for water, of which Neuman asserts it will abstract from the atmosphere 6.25 of its own weight.

When sulphuric acid is mixed with water, much caloric is evolved, and the specific gravity of the compound is greater than intermediate. The mixture of four pounds of acid, with one of water, will raise the thermometer to 300°.

Sulphuric acid decomposes alcohol and the oils; when assisted by heat, it decomposes most of the metallic oxides, and most readily those which contain the greatest quantity of oxygen, as the red oxide of lead, the black oxide of manganese.

It oxidizes iron, zinc, and manganese in the cold. Assisted by heat, it oxidizes silver, mercury, copper, antimony, bismuth, arsenic, tin, and tellurium. At a boiling heat, it oxidizes lead, cobalt, nickel, and molybdenum. It has no action upon gold, platina, tungsten, or titanium.

It unites readily with all the alkalies, and alkaline earths, also with alumine, and zircon; with which, and most of the metallic oxides, it forms salts, which are called sulphates; thus *sulphate of potass*, formerly called vitriolated tartar, is a combination of the sulphuric acid and potass, and *sulphate of soda* (Glauber's salts,) is a combination of sulphuric acid and soda.

SULPHUROUS ACID.

If sulphuric acid be deprived of part of its oxygen, it is converted into *sulphurous* acid; but the quantity of oxygen which must be abstracted to effect this change or, in other words, the quantity of oxygen which is contained in sulphurous acid, has never been ascertained.

Sulphurous acid is the result of a very slow combustion of sulphur; whereas, in a rapid combustion, the sulphur combines with more oxygen, and forms sulphuric acid.

It is usually procured by mixing, with sulphuric acid, oil, grease, metals, or any other substance that has a stronger affinity for oxygen than sulphuric acid, and proceeding to distillation. Sugar is one of the best substances which can be employed. By this means, the acid may be obtained in a gaseous form, in which state it is colourless and invisible, like common air, exhales the odour of burning sulphur, and cannot be breathed without suffocation. Extreme cold converts it into a liquid. When combined with water, for which it has a strong attraction, it does not entirely lose its smell like sulphuric acid.

Blue vegetable colours are reddened by sulphurous acid, previous to their being discharged.

This acid does not oxidize so many of the metals as sulphuric acid. The metals upon which it has this effect, appear to be only iron, zinc, and manganese.

With the alkalies, alkaline earths, alumine, and some of the metallic oxides, it forms the salts called sulphites.

TARTARIC ACID.

A HARD substance is found adhering to the sides of casks in which some kinds of wine have been fermented: this substance is tinged with the colour of the wine; but, when it has been purified by solution, filteration, and crystallization, it constitutes the salt called *cream of tartar*. Cream of tartar consists of potass, united to a peculiar acid: this acid is tartaric acid. Cream of tartar is *supertartrate of potass*.

To obtain tartaric acid, four parts of supertartrate of potass may be boiled in twenty parts of water, and one part of sulphuric acid added gradually. By continuing the boiling, the sulphate of potass will fall down. When the liquor is reduced to one-half, it is to be filtered, and if any more sulphate be deposited by continuing the boiling, the filtering must be repeated. When no more is thrown down, the liquor is to be evaporated to a syrup; and thus crystals of tartaric acid equal to half the weight

of the tartar employed, will be obtained. These crystals readily dissolve in water, and the solution crystallizes by evaporation.

The tartaric acid does not oxidize platina, gold, silver lead, bismuth or tin; and its action on antimony and nickel is very slight. It unites with the alkalies, and most of the earths. The salts formed with it are called *tartrates.*

The supertartrate of potass, from which this acid is obtained, is much used in medicine; it is cooling, and gently aperient: in domestic economy, it is dissolved in water, and, with the addition of a little sugar and a few slices of lemon, forms, after standing a day or two, an agreeable beverage, called *imperial water.* An infusion of green balm, instead of water, improves this liquor.

Mixed with an *equal* weight of nitre, and thrown into a red hot crucible, supertartrate of potass detonates, and forms the *white flux;* with half its weight of nitre, it forms the *black flux;* and by simple mixture with nitre in various proportions, it is called *raw flux.* It is, likewise, used in dyeing, gilding, whitening pins, and other arts.

TELLIRIC ACID.

The oxide of tellurium combines with many of the metallic oxides, acting the part of an acid, and producing a class of compounds which have been called tellurates.

TUNGSTIC ACID.

This acid has been found only in two minerals; one of which, formerly called tungsten, is a tungstate of lime, and is very rare; and the other, more common, is composed of tungstic acid, oxide of iron, and a little oxide of manganese. The acid is separated from the latter in the following way:—The wolfram, cleared from its silicious *gangue,* and pulverized, is heated in a mattrass, with five or six times its weight of muriatic acid, for half an hour. The oxides of iron and manganese

being thus dissolved, we obtain tungstic acid in the form of a yellow powder. After washing it repeatedly with water, it is then digested in an excess of liquid ammonia heated, which dissolves it completely. The liquor is filtered and evaporated to dryness in a capsule. The dry residue being ignited, the ammonia flies off, and pure tungstic acid remains. If the whole of the wolfram has not been decomposed in this operation, it must be subjected to the muriatic acid again.

It is tasteless, and does not affect vegetable colours. The tungstates of the alkalies and magnesia are soluble and crystallizable, the other earthy ones are insoluble, as well as those of the metallic oxides. The acid is composed of 100 parts pure metallic tungsten, and 25 or 26.4 oxygen.

TUNGSTOUS ACID.

What has been thus called appears to be an oxide of tungsten.

ZUMIC ACID.

An acid produced from vegetable substances, which have undergone acetous fermentation. Its claim to be considered as a distinct compound is doubtful. (See *Nuncic Acid.*)

ZOONIC ACID.

In the liquid procured by distillation from animal substances, which had been supposed only to contain carbonate of ammonia and an oil, Berthollet imagined he had discovered a peculiar acid, to which he gave the name of zoonic. Thenard has demonstrated, however, that it is merely acetic acid combined with animal matter.

OF ALKALIES.

Alkalies are possessed of the following properties:

1. They are soluble in water; 2. they have an acrid and urinous taste; 3. they are incombustible; 4. they change most vegetable blues to green, and the yellow to a brown; 5. they form neutral salts with acids; 6. they render oils miscible with water.

Potass and soda are called *fixed* alkalies, because they are not volatilized except by an intense heat; ammonia is called the *volatile* alkali, because it is dissipated or converted into gas at a moderate heat.

Oxygen is a compound part of all the alkalies, and appears clearly in the case of two fixed alkalies, to be the alkalizing principle. The bases of the alkalies are metals.

Table of saline products of one thousand pounds of ashes of the following vegetables:

	SALINE PRODUCTS.
Stalks of Turkey wheat or maize,	198 lbs.
Stalks of sun-flower,	349 "
Vine branches,	162.6 "
Elm,	166 "
Box,	78 "
Sallow,	102 "
Oak,	111 "
Aspen,	61 "
Beech,	219 "
Fir,	132 "
Fern cut in August,	117 "
Wormwood,	748 "
Fumitory,	360 "
Heath,	115 "

POTASS.

If the ashes of burnt vegetables be repeatedly lixiviated, until they cease to communicate any taste to the water, and the water be evaporated to dryness, a saline residue is obtained, which in commerce is known by the name of *potash*. It has been called the *vegetable alkali*, because it was supposed to be furnished by vegetables only.

Potash contains a number of foreign salts, and other impurities; but when deprived of all these, it is called by chemists *potass*.

Pure potass is extremely white, and so caustic, that if applied to the hand, the skin is instantly destroyed; it is therefore in this state called *caustic alkali*.

The potash of commerce is always combined with carbonic acid, for which it has a strong affinity, and it is this addition which disguises its properties more than all the rest, and reduces it to its usual state of what is called *mild* alkali, or by chemists *carbonate of potass*, or rather *sub-carbonate of potass*, as it is not saturated with the carbonic acid.

If potash be dissolved in water, and mixed with an equal quantity of quick-lime made into a paste with the same fluid, the lime having a greater affinity for the carbonic acid than the potass, will combine with it; the potash remains in solution, and may be separated from the lime by filteration. The evaporation of this solution should be performed in close vessels, otherwise the potass will abstract carbonic acid from the air.

Potass is soluble in its weight of water. It attracts moisture from the gases with avidity; and, therefore, affords the means of drying them. It is soluble, also, in alcohol, which is not the case when it is in a state of carbonate.

By exposure to heat, potass becomes soft; and at the commencement of ignition, it melts into a transparent glass; by increasing the heat, it is volatilized.

Potass and silex, when fused together in equal quan-

ties, combine, and form *glass*. If the proportion of potass to that of silex be as three or four to one, the glass will be soft and soluble in water. This composition is called *siliceous potass*, or *liquor of flints*.

If a solution of potass be boiled upon silex recently procured, it dissolves a part of it. As the solution cools, it assumes the appearance of a jelly, even though previously diluted with seventeen times its weight of water.

Potass, combined with fixed oils, forms soap.

It combines with sulphur, both in the dry and the humid way, forming *sulphuret of potass*. When this sulphuret is obtained by the fusion of its component parts, it is of a brown colour, soluble in water, and soon attracts water from the atmosphere. When it has acquired moisture, it is then in a state to act on the air, from which it will abstract oxygen; and, if inclosed with a quantity of it in a jar, the nitrogen will be left alone.

Sulphuret of potass, allowed to remain moist in the atmosphere, is at length converted into sulphate of potass; for the sulphur, combining with oxygen, forms sulphuric acid, and the water is decomposed, giving out sulphuretted hydrogen gas.

SODA.

Soda, called also mineral, or *fossil alkali*, because it was considered as exclusively derived from the mineral kingdom, is nearly similar to potass in its properties.

Soda is one of the most abundant substances, but is never met with naturally, except in a state of combination. It forms common salt when combined with muriatic acid, and this acid is, therefore, called *muriate of soda*. Hence, those inexhaustible mines of salt which are found in England, Poland, and other countries, and even the ocean itself, which holds it in solution, are so many vast depositaries of soda.

The French chemists have attempted to obtain muriatic acid and soda, by the decomposition of sea-salt, but the process is too expensive for general use. The soda

of commerce is therefore obtained from the ashes of marine plants, and from one of these (the *salsola soda*) it derives its name. In Scotland, this and other sea-weeds are collected, dried, and burned in pits dug in the sand, or in heaps surrounded by loose stones. Fresh quantities are added, as the first are consumed, and a hard residuum is obtained, which is of a black or bluish colour; it is called *kelp*, and contains from $2\frac{1}{2}$ to 3 per cent of soda. On the coasts of France and Spain the same kind of manufacture is carried on, and the produce is called *barilla*. The barilla of Alicant is much noted.

Soda is obtained from kelp and barilla by lixiviation, filteration, and crystallization. These processes leave it in the state of a carbonate, but it may be deprived of its carbonic acid, and rendered caustic, by lime, in the same manner as potass.

Potass and soda, in a state of purity, cannot be distinguished by inspection from each other. The oxalic acid has been used as a test to distinguish them. This acid, with potass, forms a very soluble salt, but with soda one of difficult solubility. A solution of the ore of platina in nitro-muriatic acid, also affords the means of distinguishing them; for the solution of potass will form a yellow precipitate, but soda gives no precipitate.

Fourcroy suggests that soda is the most proper of the two fixed alkalies to be employed in medicine; because animal substances always contain it, but they never contain potass.

If potass be exposed to the atmosphere, it deliquesces, that is, acquires moisture; if soda be exposed in the same manner, it effloresces, that is, parts with moisture, and is converted into a dry powder.

Soda is preferred to potass in most manufactures, its affinities in general are not so strong as those of potass, it is therefore less corrosive. It is more fusible alone, and fuses silex more readily than potass, hence it is employed in manufacture of glass.

Carbonic acid renders soda, as well as potass, fit for many purposes to which, in its caustic state, it would

not be applicable. It is in this state that these alkalies are employed, in medicine, and in washing linen.

The combination of potass or soda with oil or tallow, forms soap; but soda forms hard soap, while potass only affords soft soap. Soda is therefore much more valuable, and generally used in the manufacture of soap, for which use it is rendered caustic, by quick-lime. Muriate of soda is added in making soap, in order to harden it. The brown or yellow soap contains a quantity of rosin. Black or green soft soap is made with the coarsest oils, and retains all its alkaline ley.

The weakest acids have the power of decomposing soap, because they have a stronger affinity for its alkali than the oil. Soap is also decomposed by metallic oxides, earths, and neutral salts. Hence the water of springs is said to be hard, because soap is not soluble in it, or rather is not decomposed by it. Solution of soap may therefore be employed to show whether water holds minerals in solution or not.

AMMONIA.

If muriate of ammonia, in powder, be mixed with three parts of slacked lime, and distilled, and the product be collected by the mercurial trough, or pneumatic apparatus, a gas is obtained, which is transparent and colourless, like common air. This gas is called *ammoniacal gas*, and is the purest state in which ammonia can be exhibited.

Ammonia has a pungent, though not unpleasant smell. Its taste is acrid and caustic, like that of the fixed alkalies, but not so strong; nor has it the property, like them, of corroding animal substances. It is not respirable. Its specific gravity to common air is as 3 to 5. When exposed to a cold of 45°, it is condensed in a liquid, which again assumes the gaseous form, when the temperature is raised.

Ammonia is rapidly absorbed by water, and the absorption goes on till the water has acquired more than a

third of its weight of it. It therefore instantly disappears if water be introduced into a jar of it; some caloric is evolved, and the specific gravity of the water is diminished. If ice be introduced into this gas, it melts and absorbs the ammonia, while at the same time its temperature is dimished. The specific gravity of water saturated with ammonia, at 60° is 9054. It is the attraction of water for ammonia, which renders it necessary to employ mercury in obtaining the gas.

Water combined with ammonia, acquires its smell, and has a disagreeable taste; it converts vegetable blues to green. It is this liquid solution of ammonia which is meant in speaking of the volatile alkali. When heated to the temperature of 130°, the ammonia separates in the form of gas. When its temperature is reduced to 46°, it crystallizes; and when suddenly cooled down to 68°, it assumes the appearance of a thick jelly, and has scarcely any smell.

Ammonia may be obtained by the dry distillation of bones and other animal matters; it is from such substances that it is obtained to supply the demand of commerce, and it is sold under the name of *spirits of hartshorn*. The product of the first distillation from bones, &c. is very impure: it is therefore improved by repeated distillations.

Berthollet's experiments evince that one thousand parts of ammonia consist of 807 parts of nitrogen, and 193 parts of hydrogen; Sir H. Davy having discovered oxygen to be the alkalizing principle in potass and soda, was convinced of the probability of its existing in ammonia. His researches confirmed this opinion, and he concludes the proportion of oxygen in ammonia to be at least 7 or 8 per cent. He also succeeded in separating from it a substance of a metallic nature. The ammonia was decomposed by galvanism in contact with mercury. The mercury, by combining with about one twelve-thousandth part of this new matter, has its identity destroyed; it becomes solid, and its specific gravity is reduced from 13.5 to less than 3.0, but its colour, lustre, opacity, and

conducting powers remain. The difficulty of obtaining and operating upon this substance, has hitherto prevented its being sufficiently known to assign its proper place in the classification of bodies.

Ammonial gas has no effect upon sulphur or phosphorus. Charcoal absorbs it, without altering its properties when cold; but when the gas is made to pass through red-hot charcoal, part of the charcoal combines with it, and forms *prussic acid.*

The two gaseous substances, ammonia and muriatic acid, combine rapidly, and form the solid substance called *muriate of ammonia*, which is the *sal-ammoniac* of commerce. This is one of the most remarkable and curious facts: separately, ammonia and muriatic acid gas are two of the most pungent and volatile substances known; in union they are hard, inodorous, not volatile, and possess but little taste.

Muriate of ammonia was formerly supplied by Egypt, but it is now made in other countries (England for instance) from soot.

Ammonia combines with oils, and forms soap; it does not combine with the metals, but it changes some of them into oxides, and then dissolves them. Liquid ammonia is capable of dissolving the oxides of silver, copper, iron, tin, nickel, zinc, bismuth, and cobalt. Its use in medicine is considerable.

PEARL-ASH.

An impure potassa obtained by lixiviation from the ashes of plants.

POTASH.

See Potass

OF SALTS.

THE compound formed by the combination of an acid with an alkali, an earth, or a metallic oxide, is called a *salt.*

The term *neutral salt,* was formerly given to all combinations of acids and alkalies, but the epithet *neutral* is now restricted to those salts in which the acid and the alkali completely saturate each other, and in which, therefore, the peculiar properties of neither can be detected.

When a salt contains an excess of acid, its state is indicated by the addition of the word *super;* and sometimes by the term *acidulous;* but the latter mode of denoting the distinction, is yielding to the former.

When the salt contains an excess of alkali, the preposition *sub* is prefixed to its name, or the epithet of alkalinous; but the first-mentioned addition is the most general and appropriate.

The *base* or *radical* of a salt, is the alkali, the earth, or metallic oxide, which is combined with the acid.

Agreeably to the principles which are adopted in forming the new nomenclature, every salt receives a compound name, denoting its base, and the acid which enters into its composition. Thus, the chemical name of common salt is *muriate of soda,* as it is a combination of muriatic acid and soda. Salt-petre is called *nitrate of potass;* because it is a combination of potass and nitric acid. Glauber's salt is called *sulphate of soda,* as it is a combination of soda with sulphuric acid; and the salts formed by all other acids are reduced to the same form of expression.

When an acid is combined with two bases, the compound is called a triple salt, and both the bases are expressed: thus, we have the *tartrate of potass and soda.* A single base, combined with two acids, is denoted with equal precision; thus, we have the *nitro-muriate of tin*

When the epithet which distinguishes the acid of a salt terminates in *ate*, it signifies that the epithet of the acid itself terminates in *ic;* thus, the sulphuric acid forms *sulphates.* When the epithet of the salt terminates with *ite*, that of the acid itself terminates in *ous;* thus, the sulphurous acid forms *sulphites.* Most of the salts ending in *ite,* extract oxygen from the atmosphere, and are converted into the former kind.

The salts form a very numerous class of bodies. Fourcroy reckons that there are 134 species; and the number belonging to each species is often considerable. There can scarcely be less than 2000 distinct salts; but I shall only notice some of the most useful.

SULPHATES.

The sulphates are in general crystallizable, have some taste, but no smell; are precipitated by solution of barytes, and afford sulphurets when heated red-hot with charcoal. They are numerous, as the sulphuric acid combines with all the alkalies, and nearly all the earths and metallic oxides.

SULPHATE OF ALUMINE.

Sulphate of alumine is formed by dissolving alumine in sulphuric acid. It has an astringent taste, is very soluble in water, and crystallizes in thin plates, which have very little consistence. It generally contains an excess of acid.

I should have omitted the mention of this salt, but to distinguish it from the following one, to which the same name is apt to be given.

SULPHATE OF ALUMINE AND POTASS, OR AMMONIA, (ALUM.)

This salt is the common alum of commerce. It has an austere, sweetish, astringent taste, and always reddens tincture of litmus. Seventy-five parts of boiling water dissolve 100 of alum, at the temperature of 60°; it is soluble in from 10 to 15 times its weight of cold water, the purest alum having the least degree of solubility. Its crystals are large. By exposure to the air it slightly effloresces. Its specific gravity is 1.7.

According to Vanquelin, alum contains of alumine 10.50, sulphuric acid 30.52, potass 10.40, water 48.58.

Two kinds of alum are found in commerce, the common and rock alum. The latter has a reddish tinge, from an admixture of rose-coloured earth; it is also the most esteemed, and sold at the greatest price, though the cause of its superiority is not well known.

The uses of alum are very extensive. In dyeing it is of considerable importance for fixing several vegetable colours. It is used in the tanning of leather, to give firmness to the skins, after they have been in the lime-pits, and in the manufacture of candles, to give consistence to the tallow. Alum may also be used to advantage in the manufacture of writing-paper, to make the paper bear ink better.

Alum is prepared in France by the artificial combination of its component parts; but in Great Britain it is obtained from a kind of slate, called *alum-slate*, which is plentiful on the north-east coast of Yorkshire, and near Glasgow; about 100 tons of the slate only afford 10 tons of alum.

Ammonia will contribute to the formation of alum as well as potass.

SULPHATE OF SODA, (GLAUBER'S SALT.)

The sulphate of soda has a strongly saline and bitter taste; its crystals are transparent, but they effloresce and fall into a white powder in the air; it is soluble in

rather less than three times its weight of water at the temperature of 60°, and in $\frac{8}{10}$ths of its weight of boiling water. It is principally used in medicine as a purgative, under the name of Glauber's salts. According to Kirwan, it contains of acid 22 parts, soda 17, and water 61.

GREEN SULPHATE OF IRON, (COPPERAS.)

This salt is the copperas or green vitriol of commerce. Its crystals are of a beautiful light-green; it has a sharp astringent taste, and is poisonous. It is soluble in 6 times its weight of water at the temperature of 60°, and in $\frac{3}{4}$ of its weight of boiling water. It is insoluble in alcohol. According to Bergman it contains of acid 39 parts, green oxide of iron 23, and water 38. It is efflorescent.

Green sulphate of iron is obtained by the decomposition of pyrites or native sulphuret of iron; and this decomposition is effected by simple exposure to air and moisture. This salt is much used in dyeing blacks and other intermediate colours, both wool and cotton, also, for the black or iron liquor of the calico printers; likewise in preparing writing ink; and by bookbinders for staining black the skins which have been tanned with oak bark.

RED SULPHATE OF IRON.

If nitric acid be distilled of the green sulphate of iron, or the solution of this salt be exposed to the air, the *red sulphate of iron* is obtained. It is deliquescent, uncrystallizable, and soluble in alcohol. Proust observes that it alone forms prussian blue with prussic acid, and strikes a black colour with gallic acid; and therefore, when these effects are obtained by operating with the green sulphate, the latter salt has derived from the atmosphere, or some other source, the additional quantity of oxygen necessary to convert its iron to the state of red oxide.

SULPHATE OF COPPER, (BLUE VITRIOL OR BLUE COPPERAS.)

The crystals of this salt, which were formerly called *blue vitriol*, are a fine deep blue. It has a strong styptic taste; insoluble in four times its weight of water, and effloresces in the air. Its specific gravity is 2.2. It is generally obtained by evaporating the water of copper-mines.

The sulphate of copper is employed as a caustic, to remove the flesh of fungous ulcers. It is dangerous to administer it internally. It is also employed in dyeing certain colours.

SULPHITES.

Sulphites have a disagreeable sulphurous taste. If exposed to the fire, they yield sulphur, and are converted into sulphates, and even by mere exposure to the atmosphere, the same change is produced. They are also decomposed by the nitric, muriatic, and other acids which do not affect sulphates. They are mostly formed artificially.

The principal sulphites are those of potass, soda, ammonia, alumine, magnesia, and barytes; none of these have been applied to purposes of any importance.

NITRATES.

The nitrates are soluble in water, and crystallizable; they deflagrate violently when heated to redness with charcoal, or other combustibles; sulphuric acid disengages from them a white vapour of nitric acid. By heat they are decomposed, and yield at first a considerable quantity of oxygen gas.

NITRATE OF POTASS, (SALTPETRE.)

Nitrate of potass, saltpetre, or nitre, is the best known and most important of all the nitrates. Its tast[illegible]

bitterish, and cooling. It is very brittle. Its specific gravity is 1.9. It is soluble in seven times its weight of cold water, and in rather less than its weight of boiling water. When mixed with one-third of its weight of charcoal, and thrown into a red-hot crucible, or when charcoal is thrown upon red-hot nitre, the combustion that ensues is exceedingly vivid and beautiful. The residuum is carbonate of potass. The combustion is still more violent, when phosphorus is used instead of charcoal.

According to Kirwan, nitre contains acid 41.2 parts, potass 46.15, water 12.65. All the nitric acid employed in the arts, is furnished by the decomposition of this salt. The sulphuric acid is employed to effect the decomposition. Considerable quantities of nitre are also used in obtaining sulphuric acid, as it supplies the oxygen for the combustion of sulphur in close chambers. The manufacture of gunpowder also requires an immense quantity.

A considerable part of the nitrate of potass consumed in Europe, is furnished by the East Indies, where the soil, being impregnated with it, yields it by lixiviation and evaporation. At Apulia, near Naples, also, there is a natural nitre-bed, in which the earth contains 40 per cent. of nitre. In Germany, France, and Switzerland, artificial nitre-beds are formed, by suffering animal and vegetable matters to putrefy in combination with calcareous and other earths. A soil of this kind attracts the nitric acid from the atmosphere. Old mortar furnishes a very proper calcareous earth for a nitre-bed.

NITRATE OF SODA, (CUBIC NITRE.)

This salt was formerly called *cubic nitre*, from its crystallizing rhombs. It is somewhat more bitter than the nitrate of potass, rather more soluble in cold water, but much less soluble in hot water. It is not of any important use, though Proust observes, that when made into gunpowder, it burns longer than common nitre, and might therefore be economically adopted for fire-works.

NITRATE OF AMMONIA.

Nitrate of ammonia has a sharp, acrid, and somewhat urinous taste; it deliquesces in the air, and is soluble in about half its weight of boiling water The only use made of it is to furnish nitrous oxide.

MURIATES.

Though the muriates are the most volatile of the salts, they are at the same time the least decomposable: they may be melted and volatilized without undergoing decomposition. They effervesce with sulphuric acid, and white acrid fumes of muriatic acid are disengaged; when acted upon by nitric acid, oxymuriatic gas is disengaged.

MURIATE OF SODA, (COMMON SALT.)

Muriate of soda, or common salt, is too well known to require any description. It is the only substance to which the term salt was formerly applied. Besides the immense quantity of it held in solution by the sea-water it exists in prodigious masses in the state of rock-salt. Its specific gravity is 2.12; and it is soluble in rather less than three times its weight of water. When pure, it is not affected by the air; but common salt is deliquescent, from the magnesia and other impurities which it contains.

Muriate of soda contains of acid 44 parts, soda 50, and of water 6.

MURIATE OF POTASS, (SALT OF FEBRIFUGE.)

This salt was formerly called *febrifuge salt of Sylvius*, and *regenerated sea-salt.* It has a disagreeable, bitter taste; its specific gravity is 1.8; it is soluble in three times its weight of cold water, and twice its weight of boiling water. When heated, it first decrepitates, then melts, and at last is volatilized without decomposition. According to Kirwan, it contains of acid 36 parts, potass 46, and water 18

MURIATE OF AMMONIA, (SAL AMMONIAC.)

Muriate of ammonia, or sal ammoniac, has an acrid, urinous taste, an opaque white colour, and a specific gravity of 1.4. It dissolves in three times its weight of cold water. It contains, according to Kirwan, 35 parts of acid, 30 of ammonia, and 35 of water.

Muriate of ammonia is employed for brightening some colours in dyeing and mixing of colours; also for preserving the surfaces of metals from oxidation in tinning; in medicine it forms an excellent diaphoretic and febrifuge, and has been advantageously applied externally as a lotion for indolent tumours.

HYPER-OXYMURIATE OF POTASS.

If a solution of potass be saturated with oxymuriatic acid gas, and then evaporated in the dark, the first crystals formed are those of common muriate of potass; when these are separated, and the solution allowed to cool, the crystals of the hyper-oxymuriate of potass are obtained. These crystals have a silvery lustre, and are insipid and cool to the taste. They are soluble in 17 parts of cold water, and $2\frac{1}{2}$ of boiling water.

The hyper-oxymuriate of potass, when mixed with charcoal and other combustibles, and heated, detonates with extreme violence. It also explodes when triturated in a mortar, or when struck with a hammer, if a small quantity of it is laid upon an anvil.

This salt consists of hyper-oxymuriatic acid 58 parts, potass 39, water 3. The oxygen is about equal to the salt in weight. It was called simply oxymuriate of potass, till Chenevix proved that the acid which enters into its composition is in the highest state of oxygenizement. He endeavoured to obtain this acid separately, but the retort containing the salt was reduced almost to powder by a violent explosion. The hyper-oxymuriatic acid has therefore never been exhibited separately.

CARBONATES.

Carbonates effervesce and yield carbonic acid, when sulphuric or nitric acid is poured upon them; all the alkaline carbonates are soluble in water, while those of the earths and metals are nearly insoluble, unless the acid be in excess.

SUB-CARBONATE OF POTASS.

The potass of commerce is always in the state of sub-carbonate; the carbonic acid considerably weakens its alkaline properties, yet it will still change vegetable colours to green, and, combined with oils, will form an imperfect soap.

SUB-CARBONATE OF SODA.

The soda of commerce is in the state of sub-carbonate, but its carbonic acid deprives it of more of its alkaline properties than it does potass. For making glass, it is used in the state of a sub-carbonate, because the heat is exposed to drive off the carbonic acid; but to form soap, it must be rendered caustic, which is effected by quicklime.

CARBONATE OF LIME.

Carbonic acid has the power of completely neutralizing the alkaline properties of lime, which it reduces to a state in which it is nearly tasteless. Under the name of chalk, marble, and limestone, we shall notice this compound.

FLUATES.

The fluates are not decomposed by heat, nor altered by combustibles: when sulphuric acid is poured upon them, they yield acrid vapours of fluoric acid, which corrodes glass. When reduced to powder, and heated

but not made red-hot, some of them become phosphorescent.

The principal fluoric salts are the fluates of lime, of soda, of potass, of ammonia, of barytes, of alumine, of silex, and of strontian; but this acid forms fluates with mercury, copper, tin, iron, nickel, and several other metals. The whole of the fluates are factitious salts except those of lime and alumine.

FLUATE OF LIME.

Fluate of lime is, in England, well known under the name of Derbyshire spar, or Blue John. It is tasteless, and nearly insoluble in water. It is not altered by the air. Its specific gravity is 3.1. When powdered, and heated upon a shovel, it emits a violet-coloured light; but this ceases if it be made red-hot. It is fused by a strong heat, and is occasionally used as a flux. It exists in the enamel of the human teeth.

FLUATE OF SILEX.

The fluoric acid gas will dissolve silex, and still retains its aerial form; but the silex is afterwards deposited in crystals.

BORATES.

The Borates are all fusible into glass, and assist the fusion of other bodies, particularly metals, and metallic oxides; with the metallic oxides, they form glass of different colours.

The principal salts of this class, are the sub-borate of soda, the borate of potass, of lime, of magnesia, and of alumine.

SUB-BORATE OF SODA, (BORAX.)

This is the only borate of any importance. It is dug out of wells in the kingdom of Thibet, and comes to us from the East Indies. It is then in a state of impurity, and is called *tincal;* when purified, it receives the name

of *borax*. It is in whitish crystals, has a styptic and alkaline taste, and converts vegetable blues to green. It is soluble in twenty times its weight of cold water, and six times its weight of boiling water. When melted into glass, it is transparent, and still soluble in water. When two pieces of borax are struck together in the dark, a flash of light is emitted. Its specific gravity is 1.740. It slightly effloresces in the air.

According to Bergman, this salt consists of 39 parts of boracic acid, 17 of soda, and 44 of water. It is much used as a flux in soldering metals with the hard solders.

ACETATES.

The acetic salts are distinguished by their great solubility in water; by the decomposition of the acid when the solution is exposed to the air; by their being decomposed by heat, and by their yielding acetic acid when mixed with sulphuric acid, and distilled.

The principal acetates are those of potass, of soda, of ammonia, of magnesia, of barytes, of lead, and of copper.

ACETATE OF POTASS.

This salt has been long known, and has been distinguished by almost a dozen different names: of which one was *secret foliated earth of tartar*. It has a sharp warm taste; its crystals are white, and in the form of thin plates. It is soluble in alcohol, in ten times its weight of water, and is deliquescent. It is used in medicine. It was formerly made from distilled or even common vinegar, but is now manufactured from pearl-ash and purified pyroligneous acid.

ACETATE OF AMMONIA.

This salt tastes like a mixture of sugar and nitre. It is extremely volatile; and cannot be crystallized, except by an extremely slow evaporation. Its crystals are long and slender, and of a pearl-white colour. It is deliquescent. Its solution has been long used medicinally under the name of *spirits of Mindererus*.

ACETATE OF LEAD, (SUGAR OF LEAD.)

This salt is formed by the solution of the white oxide of lead in the acetic acid. It has a sweet and somewhat astringent taste; and is sparingly soluble in water. It becomes yellow by exposure to the air. Like all other preparations of lead, it is a strong poison, but in doses of a very few grains, it has been administered, with evident advantage, in desperate cases of internal hemorrhage. Its solution in water is used internally as an embrocation. That decomposes it. It is used considerably by the calico-printers in colour-making, &c.

ACETATE OF COPPER.

Acetate of copper has a disagreeable, coppery taste; a fine deep green colour, some degree of unctuosity, is efflorescent, and is soluble in water and alcohol. It is used in dyeing: a small quantity of it does very well in writing-ink. It is also used in painting. In chemistry, it is distilled for the acetic acid it affords.

TARTRATES.

The tartrates are decomposed by a red heat. The earthy tartrates are less soluble than the alkaline; but they are all capable of combining with another base, and forming triple salts.

The principal tartrates are those of potass, of potass and soda, of potass and ammonia, of lime, of strontian, and of potass and antimony.

SUPER-TARTRATE OF POTASS

Is the cream of tartar of the stores. It has a strong, but not disagreeable acid taste; is soluble in thirty times its weight of boiling water; and is not altered by the exposure to the air. According to Bergman, it contains 23 parts of potass, and 77 of acid. It is used in medicine as a mild aperient. It is also useful in dyeing.

TARTRATE OF POTASS AND SODA.

This triple salt is sold by the druggists under the name of *Rochelle salts*. It has a strongly saline bitter taste; is effervescent, and is soluble in about four times its weight of cold water. It is a mild cathartic.

TARTRATE OF POTASS AND ANTIMONY

The crystals of this triple salt are of a white colour, and transparent. It is soluble in 60 parts of cold water. It is formed by precipitating the muriate of antimony with a hot solution of potass in distilled water. The precipitate being well washed and dried, nine drachms are to be boiled in five pounds of water, with two ounces and a half of super-tartrate of potass, finely powdered, till the powders are dissolved. The solution must then be strained, evaporated to a pellicle, and left to crystallize. In doses of from two to four grains, this is the best and most powerful emetic known.

PHOSPHATES.

The phosphates are capable of vitrification; are partially decomposed by sulphuric acid; are phosphorescent at a high temperature; are soluble in nitric acid, without effervescence; and may be precipitated from their solutions by lime-water.

The principal phosphates are those of potass, of soda, of ammonia, of lime, and of magnesia.

PHOSPHATE OF SODA.

The phosphate of soda has nearly the same taste as common salt; it is soluble in water, and efflorescent. As a cathartic, it is equivalent to Glauber and Rochelle salts, and as its taste is much pleasanter, it has been used instead of those well-known medicines. It may be administered by dissolving in a weak broth, to which it

serves as an agreeable seasoning. Dr. Pearson first prepared and introduced it. It is used in the arts as a flux instead of borax.

PHOSPHATE OF SODA AND AMMONIA.

This compound, which was formerly called *nicrocomic salt*, is much used as a flux in assays with the blowpipe. It may be obtained from human urine by evaporation.

PHOSPHATE OF LIME.

Phosphate of lime is white, tasteless, and insoluble in water. As it forms the bases of bones, it has been some times called the *earth of bones*. It exists in milk, and some other animal products, also in wheat. In Spain it has been found abundantly in the fossil state.

PRUSSIATES.

The singular affinities of some prussiates render them interesting to the chemist; the simple prussiates are, however, little regarded, because destitute of permanency, being decomposed merely by exposure to the air, unless united with a metallic oxide. The prussic acid does not appear capable of saturating an alkali; and the weakest acid known is capable of decomposing the prussiates of the earths and the alkalies.

The most important of the simple prussiates is that of iron; and of triple prussiates, those of potass, soda, lime, and ammonia with iron.

PRUSSIATE OF IRON.

The prussiate of iron, or prussian blue, is, according to Proust, a combination of the prussic acid and red oxide of iron. With the green oxide, the prussic acid forms a white compound, which, however, becomes gradually blue by exposure to the atmosphere, from the absorption of oxygen. It is a fine deep blue, and valuable as a pigment; it is insoluble in water, very sparingly

soluble in acids, and not affected by exposure to the air It is composed of equal parts of the acid and the oxide. If exposed to a strong heat, the acid is destroyed, and the residuum is simply oxide of iron. If the blue prussiate of iron be deprived of part of its acid, by digesting it with alkalies, it becomes yellowish.

PRUSSIATE OF POTASS AND IRON.

This compound is often called prussian alkali, or prussian test. The importance of it to chemists, consists in its being capable of indicating whether a metal be present in any solution whatever, unless the metal be platina; and the colour of the precipitate differing with the metal, even the name of the metal may be known. It is necessary to take great care to have it perfectly prepared, otherwise it will afford false results. We have given Henry's directions respecting its preparations under the head of prussic acid. Its crystals should be well preserved in a well stopped bottle filled with alcohol in which they are insoluble.

OF OXIDES.

When the oxygen united to any of the simple substances does not give it the properties of an acid or an alkali, the compound is called an *oxide*.

Most of the metals are capable of combining with different proportions of oxygen, and a difference in the proportion of oxygen gives a different colour to the oxide.

Some oxides require only an additional quantity of oxygen to convert them into acids; others always retain the character of oxides, whether possessed of the highest or the lowest quantity with which they will combine.

Oxides cannot be formed except oxygen be present, and the oxide of any substance is heavier than the substance itself, by a quantity exactly equal to the oxygen received. The young student may be reminded, that by the term heavier, it is not meant that the density or

specific gravity of the oxide is greater than its base, but the total quantity of it weighs more.

Oxides are in general friable or pulverulent, and have the appearance of earths; but one of them is a fluid, and some of them are gases.

OXIDES OF NITROGEN.

Nitrogen combines in two proportions with oxygen, without producing an acid. It therefore furnishes two oxides, which are distinguished from each other, like the acids, by a difference in the termination of the word denoting the base; they are the *nitrous oxide* and *nitric oxide.*

Nitrous oxide.—This gas, which is also known by the name of *gaseous oxide of nitrogen,* is composed of 63 parts of nitrogen, and 37 of oxygen by weight. It has a faint smell, and imparts a slight sensation of sweetness, when respired. It is dissolved by water; but may be expelled from the water by heat unchanged. Alcohol absorbs more of it than water, and the essential and fixed oils more than alcohol; but heat expels it from all these combinations. It supports combustion with more activity than common air; but it is, in general, necessary that the combustible should be kindled in the atmosphere or oxygen. It may be respired for a few minutes; and the extraordinary effects it produces on the system, during its respiration, and for a short time after, occasions it to be frequently made for this purpose, which is the only use, (if it may be called use,) to which it may be applied. To inhale it superinduces a species of intoxication; the mind of the person is lost for a moment to a right consciousness of things around him. In general, he laughs involuntarily and extravagantly; exhibits the most frantic or preposterous gesticulations, and violent muscular exertion, and feels, at the same time, delightfully happy. In a few moments, after having ceased to breathe the gas, its effects go off. With nearly all persons who have breathed this gas, not the least uneasiness or languor subsequently remains; it has even re

covered some from a state of casual debility, and restored them to comfortable enjoyment; but, as there are others on whom less favourable effects have been produced, it may be a useful caution for those who have never breathed it, or who are not in perfect health, to take, in the first instance, but a small dose.

As it is important that the nitrous oxide intended to be inhaled should be perfectly pure, it may be proper to observe, that it can only be prepared with certainty by the decomposition of nitrate of ammonia. For this purpose, nitric acid, diluted with five or six parts of water, may be saturated with carbonate of ammonia, and the solution evaporated by a gentle heat, adding, occasionally, a little of the carbonate, to supply what is carried off. The nitrate crystallizes in a fibrous mass, unless the evaporation has been carried so far as to leave it dry and compact.

The nitrate should be put into a retort, and a lamp furnace should be employed to decompose it; as the heat employed should not be raised above 450°. A pound of the nitrate of ammonia will yield about 5 cubical feet of the gas, which should be received over water, and afterwards allowed to stand an hour or two in contact with the water, which will absorb any ammonia that may have been sublimed, or any acid that may happen to be present.

Nitric oxide, (sometimes called *nitrous gas*.) This gas is composed of 44 parts of nitrogen, and 56 of oxygen by weight. It is an invisible gas, until it comes in contact with the atmosphere, or some air which contains oxygen, when it assumes an orange colour. It is interesting to observe the difference between this gas, and the preceding, from which it only differs in containing a few parts more oxygen; this gas instantly kills the animals which breathe it; and even destroys plants. In general, also, it extinguishes light, but some substances have the property of decomposing it, if inflamed before being put into it, and of then burning with considerable splendour.

Dr. Priestley found that water was capable of absorb-

ing about one tenth of nitric oxide, from which it acquired an astringent taste; and that the water gave out the whole of this gas when passing to the state of ice. Oils greedily absorb nitric oxide, and decompose it. Nitric acid also absorbs it, and is converted by the absorption into nitrous acid, becoming fuming and coloured at the same time.

Nitric acid is composed of 75 parts of oxygen and 25 parts of nitrogen; it, therefore, bears a very near relation to this gas, which may be converted into it, by simply mixing it with a due proportion of oxygen.

OXIDE OF HYDROGEN.

Hydrogen appears to be capable of combining with oxygen only in one proportion, and that one forms water, which is the oxide of hydrogen.

CARBONIC OXIDE.

Carbon, combined with 60 per cent. of oxygen, forms *carbonic oxide*, which is an invisible and elastic gas, of rather less specific gravity than common air. This gas is not fit for respiration, nor will it support combustion; but it will itself burn, with a lambent blue flame, in atmospheric air. This is the only oxide of carbon which has been obtained.

OXIDE OF SULPHUR.

Sulphur, if kept for some time in fusion in an open vessel, absorbs about 2.4 per cent. of oxygen. This is the only oxide of it which is known; it is of a red colour, and is used for taking impressions of metals.

OXIDE OF PHOSPHORUS.

The brown colour which phosphorus acquires by exposure to the air, is in consequence of its combination with oxygen, and this brown part is the *oxide of phosphorus*. Phosphorus when mixed with its oxide, which it generally is when newly prepared, may be purified by putting it into hot water; the oxide swims on the surface.

METALLIC OXIDES.

Metallic oxides are exceedingly numerous; every metal is capable of forming at least one oxide, and most metals are capable of forming several by combining with different proportions of oxygen. The oxygen which enters into their composition, has the singular effect of depriving them entirely of their lustre and cohesion, and reducing them to the state of earths.

An acid has no action upon a metal, unless the oxygen it contains has a greater attraction for the metal put into it, than for the base of the acid. The acids first impart oxygen to metals, and then dissolve the oxide.

The metals, in the readiness with which they imbibe oxygen, and the firmness with which they retain it, differ very considerably. From some, as manganese, it cannot be separated without difficulty; from others, as gold, silver, and platina, it is ever ready to separate, because of their slight affinity for it, which constitutes their disposition to resume their metallic state, and is the leading property of what are called noble metals.

From the beauty and fixedness of the colours of many of the metallic oxides, they are used as pigments in painting in oil and water colours; and as they are convertible into glass, they are admirably adapted for painting on enamel and porcelain. A purple colour is given by gold; yellow by silver: green by copper; red by iron; blue by cobalt; and violet by manganese.

As carbon and hydrogen have a stronger attraction for oxygen than other substances, they, or the substances consisting chiefly of them, are employed for reducing metallic oxides; the metallic oxide is mixed up with charcoal, oil, fat, resin, or the cheapest inflammable body which can be obtained, and submitted in a crucible to a strong heat; the oxygen of the oxide combines with the hydrogen or carbon which is present, and the metal is obtained in its metallic state at the bottom of the crucible.

ORGANIC SUBSTANCES.

VEGETABLES.

Vegetables, though infinitely diversified in their appearance and properties, are found to consist of a smal. number of simple substances; carbon is the basis of them all, and after carbon, hydrogen and oxygen may be considered as forming the principal part of them. Some vegetables contain nitrogen, others phosphorus, earths, and metals, but these elements are not general; they belong only to particular plants, or to plants in particulai situations.

Although the proportions of the component parts of vegetables may be ascertained with considerable accu racy, yet the chemist is unable to combine these component parts in any manner that shall produce substances resembling the entire vegetable, or the compounded products which it affords.

Plants derive a principal part of their nourishment from water; their roots imbibe the water, which is decomposed in them, by the assistance of light and heat; and a part of its hydrogen becomes fixed, while a part, at least, of the oxygen is given out by transpiration. Water will hold carbon in solution, deriving it from the soil; and hence the utility of dung, or putrefying animal or vegetable substances, which supply a large quantity of carbon, as well as hydrogen and nitrogen. Plants will grow, although their roots stand in such materials as lose no portion of their weight, and although they be watered with distilled water. In this case, the carbon of the plants is derived from the atmosphere, through the medium of the leaves. Perhaps, at all times, the atmosphere furnishes a part of the carbon, through the medium of the under-surface of the leaves; but when an adequate supply is derived from the roots, the leaves perform this office with less energy. Water impreg-

nated with carbonic acid gas, renders vegetation more vigorous.

The processes of vegetation have a considerable tendency to produce equality of temperature. If the bulb of a thermometer be plunged into a hole in a tree, it indicates a higher temperature than the atmosphere in cold weather, and a lower temperature in hot weather.

The most usual compound substances, furnished by vegetables, and which are possessed of remarkable or distinct characters, we shall consider separately.

SUGAR.

Sugar is afforded by most plants, and in some, such as the sugar-cane, the beet-root, the sugar-maple, the carrot, it is particularly abundant. It crystallizes, is sweet to the taste, and soluble in water and alcohol. Used as food, it is extremely nourishing and antiseptic. Treated with nitric acid, it affords oxalic acid. Lime barytes, magnesia, and strontian, are soluble in the solution of sugar. One hundred parts of sugar, contain of carbon 28 parts, of hydrogen 8, and of oxygen 64.

STARCH, OR FECULA.

Starch is white, insipid, insoluble in cold water or alcohol, but forming with boiling water a semi-transparent jelly. It is abundant in potatoes, wheat, barley, and many other plants, roots, and seeds, and may be separated from them by maceration in water. It dissolves in cold water that contains an acid or an alkali.

Fecula is often used as a general term for all matters contained in the juices of plants, and not held in solution by them; sometimes we hear of *amylaceous fecula* this is the same with starch; *green fecula* is also an expression in use, but the green colour of fecula is seldom permanent. Indigo is a blue fecula.

ALBUMEN.

Albumen is most abundant in those vegetables which ferment and afford a vinous liquor without yeast. It is soluble in cold water; but its chief characteristic is, that it coagulates and becomes insoluble by heat.

GLUTEN.

If wheaten flour be kneaded in cold running water, the water will carry off the mucilage and starch it contains; and, when the water runs off colourless, a peculiar substance will remain, which is called *gluten*.

Gluten composes about one-twelfth of the matter of wheaten flour; it is ductile and elastic, and of a stringy texture: it has some smell, but no taste. If stretched out, it returns to its original state. By exposure to the air, it becomes brown, and appears to have an oily coating. When completely dry, it is very brittle, and resembles glue. If kept moist, it soon putrefies. It is insoluble in water, alcohol, or ether; but the acids dissolve it, and the alkalies precipitate it. No other vegetable product has so near an alliance to animal matter, both in its appearance, which is like that of tendons, and in its constituent parts, into which nitrogen largely enters, and some ammonia.

GELATINE.

Gelatine, or jelly, has some resemblance to albumen, but differs from it in not being coagulated by heat. It is soluble in water, insipid, and precipitated by infusion of galls. It may be procured from blackberries, and other fruits of a similar kind.

BITTER PRINCIPLE.

The bitter principle of vegetables is soluble in water and alcohol. It is soluble in nitric acid, and precipitated by nitrate of silver. Its colour is yellow, or brown. Hops, quassia, &c. contain much of it.

NARCOTIC PRINCIPLE.

The narcotic principle is soluble in 400 parts of hot water; alcohol dissolves a twenty-fourth part of it. It is crystallizable, and of a white colour. It is soluble in all the acids without heat, and is precipitated from them in a white powder by alkalies.

EXTRACTIVE MATTER.

Extractive matter is taken up from vegetables by water and alcohol; and, therefore, is soluble in these fluids. It is insoluble in ether. It is precipitated by oxymuriatic acid, muriate of tin, and muriate of alumine, but not by gelatine. It dyes a fawn colour. In the roots of liquorice, it is abundant.

TANNIN.

Tannin is the name given to the peculiar principle which combines with the gelatine of skins, and converts them into leather. It is found in the gall-nut, and in all vegetables, or parts of vegetables, which are called astringent. It has by some been deemed the astringent principle. It is soluble in water and alcohol, but is precipitated by gelatine, with which it forms an insoluble compound, that becomes solid and elastic.

WAX.

Wax is in its composition very analogous to fixed oil. It is a vegetable product: bees are merely the labourers by whom it is collected; they do not alter its nature. If the nitric or muriatic acid be digested for several months upon a fixed oil, the oil passes to a substance resembling wax. Hence wax might be inferred to be a fixed oil concreted by the absorption of oxygen. Its natural colour is yellow, but it may be whitened by exposing it in thin laminæ to the air and sun. Alkalies dissolve wax, and render it miscible with water.

In China and in North America, wax is obtained directly from plants, and is then called vegetable-wax.

HONEY.

Honey, like wax, is gathered by bees, ready formed from flowers, which contain it in an organ called a nectary; it is deleterious when gathered in districts where poisonous shrubs abound, of which there are many examples in the uncultivated parts of America. Honey is composed of sugar, mucilage, and water.

BIRD-LIME.

Bird-lime is of a greenish colour, has the smell of linseed oil, is insipid to the taste, and is extremely viscid. It is perfectly soluble in ether, sparingly so in alcohol, and insoluble in water. By exposure to the air, it becomes dry enough to be powdered, but recovers its viscidity by wetting it. It reddens tincture of litmus.

The best bird-lime is supplied by the middle bark of the holly, which is boiled in water, left to ferment for several weeks, and afterwards macerated in water.

COLOURING MATTER.

The colouring matter of vegetables is combined with, 1, the extractive principle; 2, with resin; 3, with fecula; 4, with gum. Most of the colouring matters of vegetables have a great affinity for the earths, particularly for alumine; and for the white metallic oxides, especially the white oxide of tin; also for animal fibrous matters, and for oxygen. On a due regard to these affinities, depends the art of dyeing.

Berthollet remarks, that those colouring matters which contain the most carbon, afford the richest and most lasting colours. Indigo is of this class.

WOODY FIBRE.

When thin shavings of wood are boiled in water, to separate the extractive matter, and afterwards in alcohol, to dissolve the resin, a residuum is obtained called the *woody fibre*. It constitutes the basis of the solid part of vegetables. It is tasteless, insoluble in water or alcohol,

but it is soluble in weak alkaline solutions, and is precipitated by acids. It is also soluble in nitric acid, and yields oxalic acid. It is not liable to putrefaction by exposure to the air. It consists principally of carbon, and therefore, when burnt in close vessels, affords much charcoal.

BALSAMS.

Balsams have a strong and fragrant smell: most of them are semi-fluids. When heated, the benzoic acid sublimes from them, which constitutes the principal distinction between them and resins. Like resins, they are obtained by incisions made in the trees affording them.

RESINS.

Resins are mostly insoluble in water, but when pure, they are soluble in alcohol, oils, ether, alkalies, and acetic acid. They are sometimes brittle, sometimes soft and tough, and they all become fluid by heat. The nitric acid converts them into tannin. By distillation, they afford volatile oil. They are all electric, and their electricity is negative. During combustion they afford much smoke.

MUCILAGE, OR GUM.

The mucilage of vegetables is usually transparent, more or less brittle when dry, though difficultly pulverable; of an insipid, or slightly saccharine taste; soluble in, or capable of combining with water in all proportions, to which it gives a gluey adhesive consistence, in proportion as its quantity is greater. It is separable, or coagulates by action of weak acids; it is insoluble in alcohol, and in oil; and capable of the acid fermentation, when diluted with water. The destructive action of fire causes it to emit much carbonic acid, and converts it into coal, without exhibiting any flame. Distillation affords water, acid, a small quantity of oil, a small quantity of ammonia, and much coal.

These are the leading properties of gums, rightly so

called; but the inaccurate custom of former times applied the term gum to all concrete vegetable juices; so that in common we hear of gum copal, gum sandarach, nd other gums, which are either pure resins, or mixture of resins with vegetable mucilage.

The principal gums are, 1. the common gums, obtained from the plum, the peach, the cherry-tree, &c. 2. Gum-arabic, which flows naturally from the acacia, in Egypt, Arabia, and elsewhere. This forms a clear, transparent mucilage with water. 3. Gum-seneca or Senegal. It does not greatly differ from gum-arabic; the pieces are larger and clearer, and it seems to communicate a higher degree of the adhesive quality to water. It is much used by calico-printers, and others. The first sort of gums are frequently sold by this name, but may be known by their darker colour. 4. Gum adragant or tragacanth. It is obtained from a small plant, a species of astragalus, growing in Syria, and other eastern parts. It comes to us in small, white, contorted pieces, resembling worms. It is usually dearer than other gums, and forms a thicker jelly with water.

GUM ARABIC.

The Egyptian thorn yields the true *acacia gum*, or gum-arabic. Cairo and Alexandria were the principal marts for gum-arabic, till the Dutch introduced the gum from Senegal into Europe, about the beginning of the seventeenth century; and this source now supplies the greater part of the vast consumption of this article. The tree which yields the Senegal gum grows abundantly on the sands along the whole of the Barbary coast, and particularly about the river Senegal. There are several species, some of which yield a red astringent juice; but others afford only a pure, nearly colourless, insipid gum, which is the great article of commerce. These trees are from eighteen to twenty feet high, with thorny branches. The gum makes its appearance about the middle of November, when the soil has been thoroughly saturated with periodical rains. The gummy juice is

seen to ooze through the trunk and branches, and, in about a fortnight, it hardens into roundish drops, of a yellowish-white, which are beautifully brilliant where they are broken off, and entirely so, when held in the mouth for a short time, to dissolve the outer surface. No clefts are made, nor any artificial means used by the Moors, to solicit the flowing of the gum. The lumps of gum-senegal are about the size of partridge-eggs, and the harvest continues about six weeks. This gum is a very wholesome and nutritious food; thousands of the Moors supporting themselves entirely upon it during the time of harvest. About six ounces is sufficient to support a man a day; and it is besides mixed with milk, animal broths, and other victuals.

Gum-arabic, or that which comes directly from Egypt and the Levant, only differs from the gum-senegal, in being of a lighter colour, and in smaller lumps; and it is, also, somewhat more brittle. In other respects, they resemble each other perfectly.

GUM SENEGAL.

See Gum-arabic.

GUM TRAGACANTH.

We are indebted to a French traveller, by the name of Oliver, for the discovery, that the gum-tragacanth of commerce, is the produce of a species of astragalus, not before known. He describes it, under the name of *astragalus verus*. It grows in the north of Persia. Gum-tragacanth, or gum-dragon, (which is forced from this plant by the intensity of solar rays, is converted into irregular lumps, or vermicular pieces, bent into a variety of shapes, and larger or smaller proportions, according to the size of the wood from which it issues,) is brought chiefly from Turkey. The best sort is white, semi-transparent, dry, yet somewhat soft to the touch.

Gum-tragacanth differs from all other gums, in giving a thick consistency to a much larger quantity of water, and in being much more difficultly soluble, or rather

dissolves only imperfectly. Put into water, it slowly imbibes a great quantity of the liquid, swells into a large volume, and forms a soft, but not fluid mucilage: if more water be added, a fluid solution may be obtained by agitation; but the liquor looks turbid and whitish, and on standing, the mucilage subsides, the limpid water on the surface retaining little of the gum. Nor does the admixture of the preceding more soluble gums promote its union with the water, or render it dissoluble, or more durable. When gum-tragacanth and gum-arabic are dissolved together in water, the tragacanth separates from the mixture more speedily than when dissolved by itself.

Tragacanth is usually preferred to other gums for making up torches, and other like purposes, and is supposed likewise to be the most effectual as a medicine.

According to Bucholtz, gum-tragacanth is composed of 57 parts of a matter similar to gum-arabic, and 43 of a peculiar substance, capable of swelling in cold water without dissolving, and assuming the appearance of a thick jelly. It is soluble in boiling water, and then forms a mucilaginous solution.

BRITISH GUM.

When starch is exposed to a temperature between 600° and 700° it swells, and exhales a peculiar smell; it becomes of a brown colour, and in that state is employed by calico-printers. It is soluble in cold water, and does not form a blue compound with iodine. Vanquelin found it to differ from gum in affording oxalic instead of mucous acid, when treated with nitric acid.

GUM COPAL.

(The American name of all clear odoriferous gums.) This resinous substance is imported from Guiana, where it is found in the sand on the shore. It is a hard, shining, transparent, citron coloured, odoriferous, concrete juice of an American tree, but which has neither the solubility in water common to gums, nor the solubility in alcohol

common to resins, at least in any considerable degree. By these properties it resembles amber. It may be dissolved by digestion in linseed oil, rendered drying by quick-lime, with a heat very little less than sufficient to boil or decompose the oil. This solution, diluted with oil of turpentine, forms a beautiful transparent varnish, which, when properly applied, and slowly dried, is very hard and durable. This varnish is applied to snuff boxes, tea-boards, and other utensils. It preserves and gives lustre to paintings, and greatly restores the decayed colours of old pictures, by filling up the cracks, and rendering the surfaces capable of reflecting light more uniformly.

CAOUTCHOUC OR GUM-ELASTIC.

Gum-elastic or Indian rubber, possesses great elasticity; is soluble in water and alcohol, is reduced to a pulp by heated spirits of turpentine, but is strictly soluble only in nitric ether and naphtha. The solution is extremely adhesive, and slow in drying.

Caoutchouc always remains soft, like leather, unless in a very low temperature; it is fusible, and burns like resins, but with less smoke.

Caoutchouc is prepared chiefly from the juice of the *Siphonica elastica*. The manner of obtaining this juice is by making incisions through the bark of the trunk of the lower part of the tree, from which the fluid resin issues in great abundance, appearing of a milky whiteness as it flows into the vessel placed to receive it, after which it inspissates into a soft, reddish, elastic resin. It is now manufactured into various articles of wearing apparel, &c.

GUM-LAC.

The improper name of gum-lac is given to a concrete brittle substance, of a dark-red colour, brought from the East Indies, incrustated on the twigs of the *Croton Luciferum*, where it is deposited by a small insect, at present not scientifically known. It is found in great quantities

on the uncultivated mountains on both sides the Ganges and is of great use to the natives in various works of art, as varnishing, painting, dyeing, &c. When the resinous matter is broken off the wood into small pieces or grains, it is termed *seed-lac*, and when melted and formed into flat plates, *shell-lac*. This substance is chiefly employed for making sealing-wax. A tincture of it is recommended as an antiscorbutic to wash the gums.

GUM RESINS.

Gum resins are distinguished from common resins by their forming milky solutions with alcohol, and by their being infusible. Their solutions with alcohol are transparent. Frankincense, scammony, aloes, and gum ammoniac, are gum resins. Both gum resins and balsams afford tannin when treated with nitric acid.

TAR.

This is obtained as a secondary product in making charcoal of resinous woods; namely of the pine and fir trees.

The general process is to mark out a circular tar hearth in the forest, of about 30 feet in diameter, which is paved with a slope towards its centre, or at least formed of a thick bed of well-rammed clay. From near the centre a trough or covered gutter is formed, which is frequently only a tree split, hollowed, and then joined together with clay, with which it is also coated to defend it from the fire. This trough ends in a cistern sunk in the ground to receive the tar as it flows from the trough

A pole, 15 or 18 feet long, being stuck upright in the centre of the hearth, the billets or fagots of resinous wood are piled round it, in a bed about 20 feet in diameter. Upon this, a bed of less diameter is made, and so on, decreasing gradually, to form a conical pile; which is covered with fresh-cut turfs, having a few openings round the pile, on a level with the ground. The whole being left for a day or two to settle, the pole in the middle is withdrawn, and the pile lighted at the bot-

tom holes. When the pile is well-lighted, the holes are stopped, and should the fire appear by any cracks in the covering, fresh turfs are laid to the place. The third day, the end of the gutter is opened next the cistern, which had hitherto been stopped, and the tar already made, permitted to run out. This opening is then closed again, and only opened two or three times a day, during the remainder of the process.

The tar thus obtained generally requires to be heated in large iron pots, to drive away the water and pyroligneous acid that runs out along with it, and cannot be separated by ladling; and also to allow the sand, and other impurities which the tar, in this rude process, has acquired, to settle, and be thus separated.

GREEN TAR.

This is made in the same manner as common tar, from the wood of those trees which have done yielding turpentine by incision.

Tar is used as a cheap varnish for wood-work; also as a raw material to make pitch.

PYROLIGNEOUS TAR.

This is a secondary product, collected in distilling wood which is not of a resinous nature, or charcoal for making gunpowder.

It may be used for the same purposes as tar; with which, however, it will not unite.

Since the use of coal gas for illumination, a secondary product has been obtained, which has partly superseded the common coal tar, which has been made in brick furnaces since the year 1740. It may be used for the same purposes as common tar; but as some prejudices exist against its use, it is mostly employed for illumination.

PITCH.

Two methods are in general use for making pitch; namely, either simply boiling the tar in large iron pots, or setting it on fire, and letting it burn, until, by dipping

a stick into it, the pitch appears to have acquired a proper consistence.

Two barrels of the best tar, or $2\frac{1}{2}$ barrels of green tar, are computed to make one barrel of pitch.

Pitch is used as a coarse varnish for ships' bottoms, also, to close the joints of carpenters' and coopers' works, to enable them to retain water.

BROWN ROSIN.

This is the residuum left in the still after turpentine has been distilled without water for its oil, and which is run, or ladled out of the still into casks, cut in half for sale.

Its colour is more or less dark, sometimes approaching nearly to black, according to the degree that the distillation has been pushed.

It is used as the base of many common varnishes and cements; also, to sprinkle on the surface of metals that are to be joined with another metal, in order to promote their union. It is, also, made with tallow into a soap.

When melted with a little vinegar, to render it clammy, it is used by violin players to rub their bows.

YELLOW ROSIN.

This is made by ladling out the brown rosin from the stills into a vessel of hot water: a violent efflorescence takes place, and the rosin absorbs one-eighth of its weight of water.

It is used for the same purposes as brown rosin, but is less hard, and, therefore, less adapted for cement. Its light colour, however, is sometimes advantageous.

ANIMAL SUBSTANCES.

Animal substances present us with the same constituent principles as vegetables: but the proportions of these principles are different. By destructive distillation they afford much ammonia, which is sparingly distributed in the vegetable kingdom; they also contain much nitrogen, of which the proportion is usually small among vegetables; and they are most abundant in phosphorus; while of carbon and hydrogen, which are abundant in vegetables, they contain but little. They are also distinguished from vegetables by their undergoing only the putrid fermentation, while vegetables, previous to this fermentation, undergo one of which the product affords alcohol, and another which affords vinegar.

The distinct compound substances derived from animals, are very numerous; we shall notice the most important of them.

GELATINE.

Gelatine, or jelly, is supplied by all the parts of animals, even bones, but is most abundant in the soft and white parts. It is perfectly soluble in warm water, but insoluble in alcohol, and has little taste or smell; on cooling, when not diffused in too large a quantity of water, it has a tremulous consistence, and becomes fluid by an increase of heat. Gelatine is prepared for the table from calves' feet and the muscular part of animals. It is a substance strongly tending to putrefaction when combined with water, and it differs from vegetable jelly chiefly in this tendency; but if it be concentrated and dried in a stove, it may be kept in a dry place for many years. In this state it forms the preparation called portable soup; it is easily soluble in boiling water, and a very small quantity of it forms a basin of soup.

When gelatine is obtained from the skin, cartilages, and refuse of animal matter, and reduced only to the consistence of a jelly, it is used in the arts under the

name of size. When the gelatine is concentrated and dried, it forms glue. The strongest glue is afforded by old animals. Isinglass is a glue which consists of the air-bladder of the beluga; a species of fish plentiful in the rivers of Russia.

Gelatine is dissolved both by acids and alkalies. Tannin forms with it an insoluble compound.

ALBUMEN.

Albumen, or coagulable lymph, exists in its purest natural state in the white of eggs, which consists almost entirely of it; it is also abundant in the humours of the eye, and the fluid of dropsy. Its properties are similar to the albumen of vegetables. It is soluble in water, before it has been coagulated by heat, but not afterwards. Alkalies dissolve the coagulum.

Albumen is coagulated by acids, and in some degree by alcohol. It speedily putrefies.

FIBRIN.

If the muscle of an animal be macerated in cold water, afterwards digested in alcohol, and in boiling water, to remove all the parts soluble by these agents, a white, insipid, fibrous substance remains, which is called *fibrin*.

Fibrin forms the principal part of the muscle. It is insoluble in water, alcohol, ether, or oils; it has neither taste nor smell; it contracts when heated, and by a stronger heat is melted. It is soluble in acids and alkalies, but not in cold liquid ammonia. Alkalies precipitate it from acids in flakes, which are soluble in hot water, and resemble gelatine. With nitric acid, it affords more nitrogen than any other substance. By destructive distillation, it affords water, carbonate of ammonia, a thick, heavy, fetid oil, traces of acetic acid, carbonic acid, and carburetted hydrogen. It also contains some phosphate of soda and of lime.

Fibrin exists in blood, by which it is deposited on the muscles. If the clotted or coagulated part of blood be

tied up in a linen cloth, and washed in water till the water ceases to receive either colour or taste from it, fibrin will remain in the linen.

Fibrin has a very near resemblance to gluten.

BONES.

Bones derive solidity from the phosphate of lime which forms a considerable part of them; cartilages which are bones in the first part of their formation, have the properties only of coagulated albumen. The gelatine and fat combined with bones, impart toughness and strength, and hence, when their quantity is diminished by age, the bones are easily broken. One hundred parts of ox-bones, according to the analysis of Fourcroy and Vanquelin, are composed of solid gelatine 51, phosphate of lime 37.7, carbonate of lime 10, phosphate of magnesia 1.3.

The enamel of human teeth contains a greater quantity of the phosphate of lime, and is destitute of gelatine. The shells of animals are a species of bones; they contain about the same quantity of carbonate of lime, that the bones of perfect animals contain of phosphate of lime.

HORN.

Horns, hoofs, nails, and quills, differ but little in their chemical characters; they are found to consist chiefly of condensed albumen, with some oil, and a very small proportion of gelatine and phosphate of lime.

Stag's horn and ivory are nearly the same as bone, and contain much gelatine.

Hair, wool, and feathers, differ but little from each other in their composition; one fourth of their weight consists of oil, on which their colour depends; they afford besides, water, ammonia, carbon, silex, and iron. Hair is soluble in alkalies, with which it forms soap.

BLOOD.

Blood, recently drawn from an animal, appears to be a thin and homogeneous fluid; but it soon separates into

two parts, the one a coagulated part, called the *crassamentum;* the other a fluid, called the *serum.*

The crassamentum is of a red colour; it contains albumen, iron, soda, and fibrin; the fibrin constitutes its basis, and may be obtained separately by washing it in water. It has all the properties of the fibrin obtained from muscular fibre. The crassamentum has a specific gravity of 1.245, whereas, that of blood is only about 1.05.

Serum is of a light greenish colour. Its taste is slightly saline, and it turns syrup of violets green; this property it owes to the uncombined soda which it contains. It is coagulable by a temperature of 156°, and is then of a greyish white colour; it, therefore, contains a large proportion of albumen; it also contains gelatine, hydrosulphuret of ammonia, soda, muriate of soda, phosphate of soda, and phosphate of lime. Acids permanently coagulate serum; alkalies increase its fluidity; alcohol coagulates it, but the coagulum is soluble in water.

When the blood, after circulating through the body, has arrived at the lungs in its way to the heart, it has acquired a dark colour; but when, in the lungs, it has been exposed to atmospheric air, it absorbs oxygen, with a minute portion of nitrogen, and parts with carbon; the consequence of this operation is its acquiring an increase of heat, and a fine crimson colour.

MILK.

Milk is usually considered as consisting of three parts; the *caseous*, *butyraceous*, and *serous*, which, upon its being allowed to stand in an open vessel, spontaneously separate from each other.

The butyraceous part, or cream, rises to the surface, and, when designed to furnish butter, it is skimmed off and, being put into a vessel in which it can be rapidly agitated, the butter separates from it. Butter, when fluid, is transparent; but it becomes opaque, as it cools and hardens. The butter of cows' milk becomes harder than that of any other animal.

The caseous, or cheesy part of milk is obtained by coagulating milk with an acid. For this purpose, in preparing cheese from cows' milk, rennet is used which is the stomach of a calf in which milk has soured. The coagulum is separated from the fluid part, to make cheese.

After the whole of the matter which is capable of coagulating is separated from milk, the serous, or watery part only remains: but rennet, from its slight acidity, does not make a complete separation. The fluid, therefore, remaining after rennet has been used, still contains saccharine particles and curd, and, under the name of *whey*, is used as a wholesome beverage. The *serum* obtained by the spontaneous decomposition of milk is acidulous, and totally devoid of nourishment.

If sweet whey be evaporated to the consistence of honey, and afterwards dried in the sun, a solid substance is obtained, which is called *sugar of milk*. If the sugar of milk thus prepared be dissolved in water, it may be clarified by whites of eggs, and will afford white crystals, after being evaporated to the consistence of a syrup. Sugar of milk is soluble in three or four parts of water: its taste is slightly sweet; and it yields, by distillation, nearly the same products as other sugar.

Milk is capable of undergoing the vinous fermentation, and, consequently, of affording a spiritous liquor. Marco Polo, who wrote in the thirteenth century, asserted, that liquor prepared from mares' milk, by the Tartars, might be taken for white wine. If milk be deprived of its cream, it will not afford a spiritous fluid.

Thenard gives the following as the component parts of milk; 1, water; 2, acetous acid; 3, caseous; 4, butyraceous; 5, saccharine; and 6, by extractive matter; 7, 8, muriate of soda, and potass; 9, sulphate of potass; 10, 11, phosphates of lime and magnesia. The acid here called the acetous, is now found to have different properties, and is called the *lactic acid*. (See *Lactic acid*.) The milk of different animals in its composition—asses' mares' and womens' milk—are the most saline and

serous; cows', goats', and sheep's, contain the most of the caseous and butyraceous parts.

CARTILAGE.

A WHITE, elastic, glistening substance, growing to the bones, and commonly called *gristle*. Cartilages are divided, by anatomists, into *obducent*, which cover the moveable articulations of bones; and *interarticular*, which are situated between the articulations and uniting cartilages, which unite one bone with another. Their use is, to facilitate the motions of bones, or to connect them together.

The chemical analysis of cartilage affords one-third the weight of the bones, when the calcareous salts are removed by digestion in dilute muriatic acid. It resembles coagulated albumen. Nitric acid converts it into gelatine. With alkalies, it forms an animal soap. Cartilage is the primitive paste into which the calcareous salts are deposited in the young animal. In the disease, rickets, the early matter is withdrawn by morbid absorption, and the bones return into the state nearly of flexible cartilage. Hence arise the distortions characteristic of this disease.

ANIMAL GLUTEN.

THIS substance constitutes the basis of the fibres of all solid parts. It resembles in its properties, the gluten of vegetables.

GLUE.

AN inspissated jelly, made from the parings of hides, and other offals, by boiling them in water, straining through a wicker basket, suffering the impurities to subside, and then boiling it a second time. The articles should first be digested in lime-water, to cleanse them from grease and dirt, then steeped in water, stirring them well from time to time; and, lastly, laid in a heap, to have the water pressed out, before they are put into the boiler. Some recommend that the water should be kept

as nearly as possible to a boiling heat, without suffering it to enter into ebullition. In this state, it is poured into flat frames or moulds, then cut into square pieces when congealed, and, afterwards, dried in a coarse net. It is said to improve by age; and that glue is reckoned the best, which swells considerably, without dissolving, by three or four days' infusion in cold water, and recovers its former dimensions and properties by drying. Shreds, or parings of vellum, parchment, or white leather, make a clear, and almost colourless glue. (See *Mechanical Exercises.*)

BITUMINOUS SUBSTANCES.

ASPHALTUM.

Asphaltum is a smooth, hard, brittle, black or brown substance, which breaks with a polish, melts easily when heated, and when pure burns without leaving any ashes. It is found in a soft or liquid state on the surface of the Dead Sea, but by age grows dry and hard. The same kind of bitumen is likewise found in the earth in other parts of the world; in China, America, particularly in the Island of Trinidad; and in some parts of Europe, as the Carpathian hills, France, Neufchatel, &c.

According to Neumann, the asphaltum of the shops is a very different compound from the native bitumen; and varies, of course, in its properties, according to the nature of the ingredients made use of in forming it. On this account, and probably from other reasons, the use of asphaltum, as an article of the *materia medica*, is totally laid aside.

The Egyptians used asphaltum in embalming, under the name of *mumia mineralis*, for which it is well adapted. It was used for mortar at Babylon.

BITUMENS.

This term includes a considerable range of inflammable mineral substances, burning with flame in the open

air. They are of different consistency, from a thin fluid to a solid; but the solids are for the most part liquefiable at a moderate heat. The fluid are,

1. Naphtha, a fine, white, thin, fragrant, colourless oil, which issues out of white, yellow, or black clays in Persia and Media. This is highly inflammable, and is decomposed by distillation. It dissolves resins, and the essential oils of thyme and lavender; but is not itself soluble either in alcohol or ether. It is the lightest of all the dense fluids, its specific gravity being 0.708.

2. Petroleum, which is from a yellow, reddish, brown, greenish, or blackish oil, found dropping from rocks, or issuing from the earth, in the duchy of Modena, and in various other parts of Europe, and Asia. This, likewise, is insoluble in alcohol, and seems to consist of naphtha, thickened by exposure to the atmosphere. It contains a portion of the succinic acid.

3. Barbadoes tar, which is a viscid, brown, or black inflammable substance, insoluble in alcohol, and containing the succinic acid. This appears to be the mineral oil in its third state of alteration.

The solid are, 1. Asphaltum, mineral pitch, of which there are three varieties: the cohesive; the semi-compact, maltha; the compact, or asphaltum. These are smooth, more or less hard or brittle, inflammable substances, which melt easily, and burn without leaving any or but little ashes if they be pure. They are slightly and partially acted on by alcohol and ether. (See *Asphaltum.*)

2. Mineral tallow, which is a white substance of the consistence of tallow, and as greasy, although more brittle. It was found in the sea on the coast of Finland, in the year 1736; and is also met with in some rocky parts of Persia. It is near one-fifth lighter than tallow; burns with a blue flame and a smell of grease, leaving a black viscid matter behind, which is more difficultly consumed.

3. Elastic bitumen, or mineral caoutchouc, of which there are two varieties. Besides these, there are other

bituminous substances, as jet and amber, which approach the harder bitumens in their nature; and all the varieties of pit-coal, and the bituminous schistres, or shale, which contain more or less of bitumen in their composition.

AMBER.

A BEAUTIFUL bituminous substance, which takes a good polish, and after a slight rubbing, becomes so electric, as to attract straws and small bodies. Amber is a hard, brittle, tasteless substance, sometimes perfectly transparent, but mostly semi-transparent or opaque, and of a glossy surface; it is found of all colours, but chiefly yellow or orange, and often contains leaves or insects; its specific gravity is from 1.065 to 1.100; its fracture is even, smooth, and glossy; it is capable of a fine polish, and becomes electric by friction; when rubbed or heated, it gives a peculiar agreeable smell, particularly when it melts, that is at 550° of Fahrenheit, but then it loses its transparency; projected on burning coals, it burns with a whitish flame, and a whitish yellow smoke, but gives very little soot and leaves brownish ashes; it is insoluble in water and alcohol, though the latter, when highly rectified, extracts a reddish colour from it; but is soluble in the sulphuric acid, which then acquires a reddish purple colour, and is precipitable from it by water. No other acid dissolves it, nor is it soluble in essential or expressed oils, without some decomposition and long digestion; but pure alkali dissolves it. By distillation it affords a small quantity of water, with a little acetous acid, an oil, and a peculiar acid.

Amber is met with plentifully in regular mines in some parts of Prussia. The upper surface is composed of sand, under which is a stratum of loam, and under this a bed of wood, partly entire, but chiefly mouldered or changed into a bituminous substance. Under the wood is a stratum of sulphuric or rather aluminous mineral in which the amber is found. Strong sulphuric exhalations are often perceived in the pits. Detached pieces are also found occasionally on the sea coast in vario

countries. It has been found in gravel beds near London. In the Royal Cabinet at Berlin there is a mass of 18lbs. weight, supposed to be the largest ever found. Jussieu asserts, that the delicate insects in amber, which prove the tranquillity of its formation, are not European. Hany has pointed out the following distinction between mellite and copal, the bodies which most closely resemble amber. Mellite is infusible by heat. A bit of copal heated at the end of a knife takes fire, melting into drops, which flatten as they fall; whereas amber burns with spitting and frothing; and when its liquified particles drop, they rebound from the plane which receives them. The origin of amber is at present involved in perfect obscurity, though the rapid progress of vegetable chemistry promises soon to throw light on it. Various frauds are practised with this substance. Neumann states as the common practice of workmen, the two following: The one consists in surrounding the amber with sand in an iron pot, and cementing it with a gradual fire for forty hours, some small pieces placed near the sides of the vessel being occasionally taken out for judging of the effect of the operation: the second method, which he says is that most generally practised, is by digesting and boiling the amber about twenty hours with rapeseed oil, by which it is rendered both clear and hard.

Werner has divided it into two sub-species, the white and the yellow; but there is little advantage in the distinction. Its ultimate constituents are the same with those of vegetable bodies in general; viz. carbon, hydrogen, and oxygen.

In the second volume of the Edinburgh Philosophical Journal, Dr. Brewster has given an account of some optical properties of amber, from which he considers it established beyond a doubt, that amber is an *indurated vegetable juice;* and that the traces of a regular structure, indicated by its action upon polarized light, are not the effect of the ordinary laws of crystallization by which *mellite* has been formed, but are produced by the same causes which influence the mechanical condition of

gum-arabic, and other gums, which are known to be formed by the successive deposition and induration of vegetable fluids.

OF CRYSTALLIZATION.

Crystals are aggregations of the particles of bodies, which have been spontaneously disposed in a regular form; and crystallization denotes the act of their formation. According to the strict meaning of the word, a crystal should be transparent, as well as symmetrical in its form; but it is now extended to opaque substances, and regularity of form is its leading characteristic.

Crystallization is of two kinds, the dry and the humid; dry crystallization refers to metals and other substances which cannot combine with water; the humid crystallization refers to fluids and gases holding solids in solution; and which never affords crystals but what contain more or less water.

The water combined with a crystal is called its *water of crystallization*. No crystals are transparent unless they contain water. The water, in thus combining with bodies, loses its caloric of fluidity.

The same substance, under the same circumstances, always affords crystals of the same figure; but excepting the circumstances which modify the natural process of crystallization, all the differences observed in the forms of crystals, are attributable to differences in the forms of the integral particles of the crystals.

Crystallization cannot take place unless the particles of bodies be at liberty to arrange themselves according to their peculiar attractions. Hence it is necessary, either that they be in a state of solution, or suspended in a fluid, in a state of extremely minute division, or in fusion. It has not been decisively proved that mere suspension will produce such a regular arrangement of particles as can be called crystallization; but admitting this to be

possible, the division of the particles which form the crystals must be carried so far as scarcely to differ from solution, and the same explanation will apply as to solution.

Suppose we have a saturated solution of common salt in water; the particles of the salt are so completely dispersed through the water, and probably so far removed from each other, that the particles of the water exert a stronger attraction on them than they exert on each other: the solution, therefore, remains perfect; but let some of the water be evaporated; it is now evident that as the same quantity of salt is contained in a less compass, the particles of the salt must have approximated each other, and are within the sphere of each other's attraction: they, therefore, aggregate and form crystals, until the solution is of the same intensity as at first. If the evaporation be resumed, more crystals are formed in the same manner, until at last, by the evaporation of the whole of the water, the crystals are obtained dry.

The crystallization of a metal is not essentially different from an aqueous crystallization. The metal may be regarded as held in solution by caloric; and, as the caloric of fluidity is withdrawn by the cooling of the metal, the case is correspondent to that of the reduction of the quantity of water in the aqueous solution, and the particles will arrange themselves according to their form. It must be obvious, that if the particles of the metal, or of the solid in solution, consist of cubes, they will aggregate in forms of one description; and, if they are tetrahedrons, they must place themselves upon each other in another.

A fluid which has furnished all, or the greater part of the crystals that can be obtained from it, is called *mother-water.*

In general, fluids at a boiling-heat hold in solution a much larger portion of any matter than when cold, because caloric has a powerful effect in lessening the attraction of aggregation, and preventing particles which are very near from combining. Common salt is, how

ever, an instance of a common salt which is nearly as soluble in cold, as in hot water: but it appears to be a general law, that salts of this kind require but a small quantity of the water of crystallization.

Salts which acquire moisture from the atmosphere, so as to become fluid or pulpy, are said to be *deliquescent:* when they lose their crystalline form in the air, and yet remain dry and powdery, it is because their water of crystallization has been abstracted; and they are said to be *efflorescent.*

A salt is deliquescent, when it has a *greater* attraction for water than the air; as it will, in that case, take water from the air: a salt is efflorescent, when it has a *less* attraction for water than the air; for the air will then abstract water from it. When the salt has the same attraction for water with the air, it will suffer no change.

The slower the crystallization, the larger, the harder, the more regular and transparent, the crystals which are formed. A rapid evaporation of a solution, therefore, produces imperfect crystals, the particles not having time to assume the exact arrangement to which they are naturally disposed.

Crystallization is promoted when the solution is furnished with some point at which it may commence.

In a saturated solution which exhibits no signs of crystallization, crystals will soon be observed, if a thread be stretched through it. But if, instead of any foreign matter, a crystal of substance in solution be introduced, the crystallization is still further promoted. Upon this fact, Le Blanc founded a method of obtaining very large and perfect crystals. He selected the largest and most perfect crystals of salt recently formed, and put them into a saturated solution of the same salt. As the side of a crystal in contact with the vessel receives no increase, they were turned daily. After a certain time, the largest and most regular crystals thus obtained were employed as the nucleus of still larger crystals, by a repetition of the process.

Kirwan observed, that if two salts be held in solution by the same fluid, a crystal of either will cause that salt to crystallize which is of the same kind as itself.

Crystallization goes on but very slowly in closed vessels; and, in most instances, wholly stops: but Dr. Higgins inferred, from his experiments, that the atmosphere only facilitates the process in consequence of its pressure; and, therefore, a sufficient column of mercury, or any other pressure, has the same effect. Perhaps the experiment has not been tried in a proper manner: the pressure upon the surface of a fluid, in a closed vessel containing air, is not less than when that vessel is uncovered.

The action of light has the effect of impeding and disturbing crystallization: and crystals are, therefore, larger, and more regular, when formed in the dark.

A very singular discovery was accidentally made by Hany, respecting the elementary forms of crystals. Happening to take up a hexangular prism of calcareous spar, which had been detached from a group of the same kind, he observed that a part of the crystal was wanting, and yet that it presented a smooth surface. Attempting to detach a segment from the contiguous edge, he could not succeed; but the ore next it was easily divided. Proceeding thus to divide the crystals mechanically, in such a way that the separation was easy, and left smooth surfaces, and which did not happen unless in directions parallel to the first fracture, he found that the crystal changed its form as parts of it were separated, until at length it acquired a form that remained mathematically the same after any subsequent sections. On trying the experiment, he found that other crystals of the same spar were reducible to the same unalterable form; and that crystals of other bodies were also reducible to fixed forms, of one kind or another. These fixed forms, therefore, he denominates the *primitive forms* of the crystals; and the other forms which crystals assume, he calls their *secondary forms.*

The primitive form of a fluate of iron, Hany found o be an octahedron; of sulphate of barytes, a prism, with rhomboidal bases; of corundam, a rhomboid, somewhat acute; of beryl, an hexahedral prism; of blend, a dodecahedron, with rhomboidal sides.

Pursuing the path which these discoveries pointed out, with a rare combination of industry and ingenuity, he succeeded in delineating a system of crystalography, which, though yet in its infancy, bears the strongest indications of remaining consistent with the phenomena of nature, and, therefore, of obtaining a permanent reception in science.

OF COMBUSTION.

Combustion is the union of a body with oxygen accompanied by the evolution of light and heat; and, therefore, every body which is capable of forming this union, is called a combustible.

Oxygen is retained in the gaseous state by the large quantity of caloric with which it is combined, and for which it has a strong attraction; but if any substance be presented to the oxygen gas, that has a stronger attraction for oxygen than oxygen has for caloric, the consequence is, that the oxygen gas is decomposed, its particles unite with the substance thus presented to it, and a great part of the caloric being then left in an uncombined state, recovers the properties which are peculiar to it in that state, that is, it assumes the appearance of fire. The heat thus produced is the more intense, the greater the quantity of caloric which is liberated in a given compass and time; and these circumstances are dependent upon the strength of the affinity between oxygen and the substance which separates it from caloric, and the quantity of caloric required to saturate the product of combustion.

At the ordinary temperature of the atmosphere, bodies have either no affinity for oxygen, or usually a very weak one; hence they suffer no change, or the change which

does take place is so slow, that though a combustion in effect, it is not called by that name, because neither light nor heat are perceptible to the senses.

When the temperature of a combustible is raised, its affinity for oxygen is increased; and when it is raised to a certain point, which varies according to the nature of the substance, the affinity becomes very strong, the combustion is consequently rapid and brilliant, taking, according to the phenomena it presents, the name of ignition, inflammation, decrepitation, detonation, or fulmination.

Light appears to form a component part of all combustible bodies, and to enter, as well as caloric, into the composition of oxygen itself. Hence, when oxygen by combustion enters into a new combination, part at least of the light held both by it and the combustible, is disengaged and flies off, as well as the caloric. In general it appears evident, that the light is furnished by the combustible, because the light furnished by different combustibles is of different colours, and the quantity of it is by no means proportionate to the quantity of oxygen consumed. For example, hydrogen in combustion combines with a greater quantity of oxygen than any other body; but the light afforded is inconsiderable.

Although the light furnished by combustion is not proportionable to the quantity of oxygen which enters into combination, and therefore is evidently not wholly furnished by the oxygen, yet the case is the reverse with the caloric evolved. The combustion of those bodies which combine with the greatest quantity of oxygen, always furnishes the greatest quantity of caloric, and therefore the combustion of hydrogen furnishes the most intense heat that can be produced, until some other substance shall be found which combines with a greater quantity of oxygen.

Another proof that the chief part of the caloric extricated during combustion is furnished by the oxygen, which when it ceases to be a gas, has no longer occasion for it, is, that when the oxygen is in combination with a fluid, a combustible substance, for example, a metal, will

abstract it from the fluid, but the usual phenomena of combustion do not appear, although the combination with oxygen is so rapid, that if the same quantity of oxygen had been derived from a gas, in the same time, these phenomena would have been exhibited with considerable splendour.

Bodies which have been once thoroughly burnt, which is only another way of expressing that they are saturated with oxygen, are incapable of undergoing combustion again, until some part or all of their oxygen is abstracted. To deprive them of their oxygen is virtually to unburn them; and when no part of a combustible has been dissipated, but only changed by the new combination, the abstraction of the oxygen absorbed restores its pristine properties. This is the case with metals, which acquire by combustion a weight equal to the oxygen combined with them, and of course lose that acquired part of their weight when the oxygen which constitutes it is withdrawn; but vegetables and other combustible matters containing many volatile parts, when burnt in the open air, have these parts dissipated, and therefore the products they afford after combustion, weigh considerably less than the vegetables themselves, as they only consist of those parts which cannot be converted into gas.

We have stated that many substances, by their union with oxygen in combustion, are converted into acids; when this happens, the combustible is said to be *oxygenized;* when the product of combustion is not an acid, it is called an oxide, and the combustible is said to be *oxidized.*

The experiments which have proved the alkalies and earths to be metallic oxides, have tended materially to establish the conclusion, that all substances are either combustible, or combined with oxygen to the point of saturation; and if this be maintained, oxygen must, like caloric, have an affinity for every substance existing.

ELECTRICITY.

A PROPERTY which certain bodies possess when rubbed, heated, or otherwise excited, whereby they attract remote bodies, and frequently emit sparks, or streams of light.

Abstract of Electricity.

1. Electricity is supposed to be a fluid, which repels its own particles, but attracts all other matter.

2. That portion of electricity which every body is supposed to contain, is called its *natural share.*

3. When a body is possessed of either more or less than its natural share, it is said to be *electrified* or *charged.*

4. If it possesses more than its natural share, it is said to be *positively* electrified: if it contains less than its natural share, it is said to be *negatively* electrified.

5. Bodies through which the electric fluid passes freely, are called *conductors*, or non-electrics. Those bodies which oppose the passage of electricity, are called *non-conductors*, or *electrics.*

6. Glass, and some other bodies, which are non-conductors at common temperature, become conductors, when very hot.

7. The equilibrium of the electric fluid is disturbed by the friction of bodies against each other; and electricity is then said to be *produced*, or *excited.*

8. Electricity is excited in the greatest quantity by the friction of *conductors* and *non-conductors* against each other.

9. The same substance, excited by a different rubber, will alternately be electrified positively and negatively.

10. Two bodies, both *positively*, or both *negatively* electrified, repel each other; whereas, if one body be *positive*, and the other *negative*, they will *attract* each other.

11. Upon this principle are constructed electrometers, or instruments for ascertaining whether bodies are electrified or not.

12. If a body, containing only its natural share of electricity, be presented sufficiently near to a body electrified *positively* or *negatively*, a quantity of electricity will force itself through the air, from the latter to the former, appearing in the form of a spark.

13. When two bodies approach each other sufficiently near, one of which is electrified *positively*, and the other *negatively*, the superabundant electricity rushes violently from one to the other, to restore the equilibrium between them. This effect also takes place, if the two bodies be connected by a conducting substance.

14. If an animal be placed so as to form part of this circuit, the electricity, in passing through it, produces a sudden effect upon it, which is called the *electric shock*.

15. The motion of electricity, in passing from a positive to a negative body, is so rapid, that it appears to be instantaneous.

16. When any part of a piece of glass or other electric is presented to a body electrified positively or negatively, that part becomes possessed of the *contrary* electricity to the side of the body it is presented to; and the other side of the glass is possessed of the same kind of electricity as the other *body*.

17. The electricity communicated to glass and other perfect electrics, *does not spread*, but is confined to the part where it is communicated, on account of the non-conducting quality of the glass.

18. To effect the communication, and to enable it to be applied to the whole surface, the glass is covered on both sides with tin-foil, or some other conductor, in which case the glass is said to be *coated*.

19. If a communication by means of a conductor, be made between the two sides of a glass thus *coated* and *charged* with electricity, a discharge takes place, by which the two sides recover their natural state.

20. The coated glass may either be flat or any other form; but cylindrical jars are found to be the most convenient form. The Leyden phial is nothing more than a glass of this description.

21. When several jars or phials are connected together so as to be charged and discharged simultaneously, they constitute an *electrical battery.*

22. Electricity is capable of producing the most powerful effects, melting the metals, and firing all the inflammable substances. A strong shock sent through metallic oxides, frequently reduces them to a metallic state.

23. The machines by which electricity is artificially accumulated, for the purpose of charging jars or batteries, are constructed with either a *cylinder* or *plate* of glass, which is whirled round in contact with a body called a rubber, and the electricity is taken off as it is produced, by a non-electric called the *prime conductor.*

24. Cylinder machines are the most easily constructed; but plate machines are the most compact and elegant.

25. Several bodies become transparent during the passage of electricity through them; a circumstance which has given rise to the conjecture that electricity may be the cause of all transparency.

26. *Metallic points* attract the electricity from bodies, and discharge them *silently.* This property has rendered them useful in defending from lightning.

27. When electricity enters a point, it appears in the form of a *star;* when it *issues* from a point, it puts on the appearance of a *brush* or *pencil.*

28. Machines may be put in motion by the electric fluid which issues from a point.

29. The shock of an electric battery will communicate magnetism to steel bars lying in or near the magnetic meridian; and a magnetic bar may have its poles reversed, or its magnetic properties destroyed, by imparting the shock while it is in different positions.

30. Electricity is evolved in heating and cooling of various bodies; also in the evaporation and condensation of vapours.

31. Vapour requires, for its natural share, a greater quantity of electricity than water, from which it was produced.

32. When a quantity of vapour is, in any degree, con-

densed, it has, therefore, electricity to give out; that is, in the positive state. When a quantity of vapour is further expanded, it requires, for its natural share, more electricity than before; that is, in the negative state.

33. By the ascent of vapour, immense quantities of electricity are carried from its reservoir, the earth; and, by the unceasing alternations of rarefaction and condensation, the atmosphere is always more or less in an electrical state.

34. *Lightning* is a vast accumulation of electricity.

35. *Thunder* is the noise produced by the solid particles of air rushing together, after having been separated by lightning; the rapidity of the motion of which is such as to produce a vacuum as it proceeds.

36. In the eruptions from volcanoes, lightning is almost always present; and earthquakes are generally accompanied by a disordered state of the atmosphere; often with great thunder-storms. Hence, electricity is supposed to be intimately connected with these phenomena.

37. In the healing art, electricity appears capable of producing, in many cases, the most excellent effects. In applying it, the general rule is to begin gently, and to continue the application, at periodical intervals, for a considerable time.

GALVANISM.

GALVANISM is a species of electricity which is produced by a peculiar action of metallic and other electrical conductors on each other.

Abstract of Galvanism.

1. Galvanism appears only to be a method of exciting electricity. The first efficient observation of its effects originated with Galvani, from whom it derives its name; but it was Volta who first rendered it interesting, by discovering the method of accumulating it.

2. Galvanic electricity is produced by the chemical

action of bodies upon each other; particularly by the oxidation of metals, during which process, considerable quantities are evolved.

3. It appears to be in a state of less intensity or condensation than the electricity obtained by the electrical machine.

4. It will oxidize metals, and set fire to all inflammable substances: it will also give a charge to a Leyden phial.

5. Of all known substances, the nerves of animals, recently dead, appear to be the most easily affected by it; and constitute electrometers of exquisite delicacy.

6. It is conducted, and refused a passage by some substances, as common electricity.

7. When a living animal forms a part of its circuit, it produces a sensation resembling that of the electric shock.

8. Electricity is *generated* by the galvanic battery; but only *collected* or *transferred* by the electrical machine; and, therefore, the effects of the former are increased by insulation.

9. The power of galvanism in consuming wires, is greatest when the plates are numerous; but in giving a shock, it is greatest when the plates are large, the quantity of surface in each case being the same.

MAGNETISM.

A PECULIAR species of attraction, excited by bodies called magnets or loadstones, receives the appellation of magnetism.

Abstract of Magnetism.

1. THAT principle which produces the phenomena of magnetism, is not cognizable by our senses, except by its effects; but it is considered to be a fluid, and spoken of under the denomination of the *magnetic fluid.*

2. Iron has been usually considered as the only substance susceptible of magnetism; but late investigations,

which have been made with great care, have rendered it extremely probable that both nickel and cobalt likewise submit to the influence of the same power.

3. Magnets are either *natural* or *artificial;* natural magnets are ores of iron, dug out of the earth in a magnetical state; artificial magnets are made of steel, by the help of a natural magnet.

4. In every magnet there are two opposite points, which at all times and places, will, if the magnet be at liberty to move either without or with very little friction, turn to the poles of the world, or nearly so.

5. It is this singular property, which is called *polarity*, that renders the magnet so useful in navigation.

6. The poles of magnets, if of the same name, as when two north or two south poles are brought near together, *repel* each other; different poles, on the contrary, *attract* each other. The centre of a magnet neither attracts nor repels.

7. The earth itself acts as a great magnet, the poles of which nearly but not quite coincide with the geographical poles.

8. It is this difference between the magnetical and the geographical poles, that produces the declination of the needle, which turns to the former, and only indicates the latter by the nearness of the two.

9. The magnetical poles are not fixed points, but the cause of their motion is unknown.

10. The constant change which the motion of the magnetic poles produces in the *declination of the needle*, is the cause of what is called the *variation of the compass.*

11. At all places not 90 degrees from the magnetic poles, one pole of a magnet suspended by its centre sinks below the horizon, which is called the *dip* or *inclination* of the needle.

12. In the northern hemisphere, it is the north pole which dips, and in the southern hemisphere it is the south pole.

13. To render a natural magnet capable of lifting a

weight with the force of both poles, it is furnished with an armature; an artificial magnet, for the same purpose is made in the form of a horse-shoe.

14. Soft iron receives magnetism with great facility, but loses it almost immediately: steel on the contrary, but especially hardened steel, is not easily affected; but the portion it receives, it permanently retains.

15. A magnet employed in the communication of magnetism, rather gains than loses strength.

16. A steel bar, rendered magnetic, and resting by its centre upon a point, so as to be at liberty to turn in any direction, is, with the box which contains it, and a card on which are written the names of the winds, called the *mariner's compass.*

17. The *azimuth compass* differs chiefly from the above in having two sights, through which may be seen the sun or any heavenly body, of which the azimuth is to be taken.

18. The dipping needle is made by accurately suspending a bar of steel, in an unmagnetical state, on the pivots of an axis passing through its centre; it is then magnetized, and dips according to the action of the north or south pole upon it.

PNEUMATICS.

The science of Pneumatics treats of the density, pressure, and elasticity of the air, and the effects which they produce.

Pneumatics, being a science somewhat remote from the present design of this work; and having the properties of the air, under the head of chemistry; we shall, therefore, let an abstract of this science suffice.

Abstract of Pneumatics.

1. The air is the fluid which we breathe; with the vapours it contains, it is called the atmosphere.

2. The particles of air are solid and impermeable, like those of the hardest bodies.

3. The air is invisible, because of its great transparency; when unconfined it is imperceptible to the touch, because its particles move among each other with a facility so great that we perceive no force to be required in displacing it; we move in it as if we had no pressure upon us, because its pressure is in every direction the same.

4. The weight of air is to that of water, as 832 to 1.

5. The air expands in proportion to the diminution of the pressure upon it; it, therefore, becomes rare as we ascend in the atmosphere: at the height of $3\frac{1}{2}$ miles, a given bulk of it takes up twice the space it would do at the surface of the earth.

6. The air-pump is a machine for exhausting the air out of vessels; but the best air-pumps have not so completely attained their object as to produce an absolute vacuum, or place void of air.

7. The rising of water in common pumps, is owing to the pressure of the atmosphere being removed from one part of the fluid, which, therefore, yields at that part by the pressure on the other parts, till the column of water sustained is equal to the column of air sustaining it.

8. *Suction*, unless so applied as to mean the pressure of the atmosphere, is a non-entity, and incapable of producing effects.

9. The pressure of the atmosphere, which is in general 15 lbs. on every square inch, is not invariably the same, but is in a middle-sized person 1866 pounds less at one time than another; and when the pressure is greatest, we feel exhilarated rather than depressed.

10. On the variable pressure of the atmosphere, and the changes thereby occasioned, is founded the utility of the *barometer*, by which instrument the pressure is measured.

11. The best barometer is the common one, with a straight tube, and short scale of variation; other kinds, in contriving which, the extension of the scale of variation has been chiefly aimed at, are all more or less defective.

12. In observations for measuring the height of moun-

tains, a thermometer must be used along with the barometer, in order that the due allowance may be made for the effects of temperature in lengthening or shortening the column of mercury; and the surface of the mercury in the cistern must be at a fixed distance from the scale, before the height of the mercury is read off.

13. The air may be condensed, or forced into less compass than it occupies at the surface of the earth, by means of a contrivance called a *condensing engine.*

14. When much condensed, the efforts of the air to expand are so great, that it may be employed as a powerful motive force. On this depend the properties of air-guns.

15. An *hygrometer* is an instrument for measuring the dryness or moisture of the atmosphere.

16. De Saussure's hygrometer is made of clarified hair; De Luc's, of a slip of whalebone cut across the grain.

17. The depth of rain which falls on the earth is estimated by the quantity which falls within a small vessel called a *rain-gauge.*

18. The strength of wind is measured by its power to support bodies out of the position of equilibrium.

19. The winds are the consequences of variations constantly taking place in the density of the atmosphere, principally by the action of solar heat.

20. Variable winds are supposed to be the chief causes of the rising and falling of the barometer, which, in countries not subject to them, remains almost uniformly at the same height.

21 In deriving from the barometer, prognostics of the weather, the tendency of the mercury to an upward or downward motion, rather than its absolute height at any time, is chiefly to be regarded.

22. When the air reaches the ear in a state of vibratory motion, it occasions the sensations of *sound.*

23. Bodies which produce the clearest and strongest sound, are in general the most elastic.

24. The quality of sound, in point of tone, is determi-

ned by the greater or smaller number of vibrations made by the sounding body in a given time.

25. Sonorous bodies, when sufficiently near, cause each other to sound, although but one of them is struck, provided they be in unison, or disposed to make vibrations equally frequent.

26. An *echo* is the reflection of a sound, and cannot be heard unless the original sound has traversed the distance of about 110 feet.

27. Speaking and hearing trumpets act upon the principle of reflecting towards their axes, and thereby concentrating the sound transmitted through them.

OPTICS.

This is a branch of Natural Philosophy which treats of the mechanical properties of light, and the phenomena of vision.

Abstract of Optics.

1. The particles of light, which are inconceivably small, proceed from luminous bodies in right lines.

2. Consequently the density of light is inversely as the square of the distance from the luminous centre.

3. Light moves at the rate of nearly 200,000 miles in one second of time.

4. Its impression on the retina is not instantaneous; hence though its particles may be separately projected, so as to be, in their progress, at the rate of 1000 miles apart, its velocity is sufficient to produce a distinct vision.

5. Every ray of light carries with it the image of the point from which it was emitted; when, therefore, pencils of rays from every point of an object are united in the same order in which they were emitted, they form an image or representation of that object, at the place where they are thus emitted.

6. All the rays of light, which enter another medium obliquely, suffer refraction; that is, they either move farther from, or nearer to, the perpendicular, as the

medium into which they enter is rarer or denser than the other medium.

7. On the refrangibility of light depends the properties of lenses.

8. Convex lenses collect the rays of light, and make them converge to a centre or focus.

9. Concave lenses disperse the rays of light, the power of refraction not being towards the centre, but towards their circumference.

10. When light strikes upon a surface, it is reflected so that the angle of reflection is equal to the angle of incidence; on this the properties of mirrors depend.

11. Plane mirrors have no other effect than that of changing the direction of the incident rays.

12. Convex mirrors cause parallel rays to diverge.

13. Concave mirrors collect parallel rays, or cause them to converge to a focus.

14. Mixed mirrors exhibit distorted images, because they increase or lessen the divergence or convergence of the rays in one or two directions only.

15. The solar beam is composed of rays possessed of different degrees of refrangibility, and these differences of refrangibility, which are dependent on the size of their particles, produce all the phenomena of colours.

16. The solar beam, or white light, contains rays of seven different colours, viz. red, orange, yellow, green, blue, indigo, and violet. These are called the primitive colours, because they are immutable, except by intermixture.

17. It is inferred that red light is composed of particles of the largest size, because it is found to be capable of struggling through thick and resisting mediums, which stop every other colour.

18. The size of the particles of other colours is in the order of their enumeration, the violet being the smallest.

19. The rainbow is owing to the separation of the light into its primitive colours, by the drops of falling rain, which act like a prism.

20. The rays of light are *inflected* when they pass very near a body, and *deflected* when they pass at a greater distance.

21. Those rays which deviate the least by refraction, deviate the most by flection.

22. The images of all visible objects are depicted on the retina, in an inverted position.

23. With two eyes, vision is not only more distinct but more accurate than with one.

24. A good eye can see most distinctly when the rays fall exactly on the retina.

25. The best eye can hardly distinguish any object that subtends an angle of less than half a minute.

26. The apparent magnitude of objects is dependent on the angle under which they are seen, or the size of their images depicted on the retina.

27. The long-sighted require convex spectacles, the short-sighted, concave ones.

28. Burning lenses must be convex, and burning mirrors concave, as the effects of both these instruments are dependent on the condensation of the incident light.

29. Microscopes are optical instruments for viewing small objects. They appear to magnify objects, because they enable us to see them with distinctness, nearer than the natural limits of vision.

30. Refracting telescopes are formed by lenses only; when manufactured in the best manner, they are either furnished with an *acromatic* object-glass, which corrects the defect arising from the unequal refraction of the different rays, by a combination of one or two convex lenses with a concave one of a different sort of glass; or, though more rarely, they have an *aplanatic* object-glass, which corrects the same defect by a combination of a plano-convex and meniscus glass, with a fluid between them that acts like a third lens.

31. Reflecting telescopes consist of lenses and at least of one speculum. When there is more than one speculum, the second is only about one-fourth of the size of the other, and may be either convex, concave, or plane.

32. Reflecting telescopes admit of a much greater magnifying power in a given length, than refracting telescopes.

33. The binocular telescope consists of two telescopes so combined, that both eyes may be employed in looking at the same object.

ASTRONOMY

Is the science which treats of the motions, eclipses, magnitudes, periods, and other phenomena of the heavenly bodies.

Abstract of Astronomy.

1. The solar system comprises the sun and all the bodies that revolve around him, viz: the comets, the planets with their respective satellites, and the asteroids.

2. The number of the comets is unknown; that of the planets, so far as yet discovered, is seven; the satellites eighteen; and the asteroids four.

3. The figure of the earth is not that of a perfect globe, but an oblate spheroid, flattened a little at the poles, by its revolution on its axis.

4. The planets Jupiter and Saturn are also observed to be flattened at the poles like the earth, but in a greater degree, evidently because their diurnal revolution is swifter.

5. The orbits of all the planets, asteroids, and comets, are ellipses, having the sun in one of their foci; but the orbits of the two former classes of bodies are nearly circular, while the orbits of the comets are all very eccentric.

6. The orbits of the satellites are also ellipses, in one of the foci of which is sustained the primary planet round which they move.

7. The periods, distances, and magnitude of the planets, have all been determined with very considerable exactness; the same circumstances respecting the asteroids,

are also evidently determinable, though the results yet laid down, have not, from the recent date of their discovery, been so amply confirmed, as to be fully relied on; but the comets recede to such immense distances, and there is so much uncertainty in identifying them, that their elements are hypothetical.

8. The planets, comets, and asteroids, are preserved in their orbits, by the joint effects of the power of attraction, which acts in a right line from them to the sun, and a projectile or centrifugal force, which would carry them off in a tangent to the curve of revolution.

9. The powers which preserve the satellites in their orbits, are the same as those that act upon the planets and comets, but the centripetal force is exercised by the primary.

10. The body of the sun is supposed to be opaque, and to be surrounded with a double set of clouds, the upper stratum of which forms the luminous globe we behold.

11. The planets revolve round an imaginary line or axis within themselves, and the time in which they perform this rotation, constitutes their *day* and *night*.

12. The time in which a planet revolves round the sun, forms its year.

13. The diversity of seasons is occasioned by the inclination of the axes of a planet to the plane of its orbit.

14. The annual and diurnal revolutions of the planets are all performed from west to east.

15. The satellites, also, revolve from west to east, with the exception of the satellites of Herschel, which appear to move in a contrary direction.

16. The fixed stars are distinguished from the bodies of the solar system, by the twinkling light they afford, by their having no parallax, and by their having, even through the best telescopes, no sensible magnitude.

17. The naked eye cannot behold above five hundred stars in the whole hemisphere; but the number discovered with the assistance of a telescope exceeds all calculation.

18. Every fixed star is supposed to be a sun, shining by its own light, and surrounded by planetary worlds like those of the solar system.

19. The tides are an effect of the attraction of the sun and moon upon the ocean. When these luminaries act together, or in the same line, they occasion spring tides; when they counteract each other's attraction, *neap tides* take place.

20. Eclipses of the moon are owing to the shadow of the earth falling upon the moon.

21. Eclipses of the sun occur, when the moon coming between the earth and the sun, throws a shadow on the earth.

22. Motion is the measure of time, and the motions of the heavenly bodies are the basis by which all other motions are measured.

23. The day is a natural division of time, that is, it comprises a portion of time measured out by the completion of certain phenomena, successive according to regular laws.

The periodical and synodical lunar months are also natural divisions of time, but no other; the year, and lunar and solar cycles, are of the same character as the lunar months; the cycle of indiction, and the olympiad, are examples of the artificial division of time.

Thirty days hath September,
April, June, and November;
All the rest have thirty-one,
Except the leap-year: that 's the time,
When February's days are twenty and nine.

MECHANICAL EXERCISES.

OF IRON.

Of all metallic substances, iron is the most abundantly diffused, and the most intrinsically valuable.

(This metal is described under the head of Chemistry.)

Iron is employed in three states, viz: that of *cast* iron, *wrought* iron, and *steel*. Cast iron is the metal in its first state, rendered fusible by its combination with those two substances which chemists distinguish by the names carbon and oxygen. In the great iron works, the ore, broken in small pieces, and mixed with a portion of limestone to promote its fusion, is thrown into a furnace, which is from 16 to 30 feet high. Baskets of charcoal or coke, in due proportion, are thrown in along with it. A part of the bottom of the furnace is filled with fire only. This being kindled, the whole is roused, by the blast of the great bellows, to a most intense heat. The metal, as it is reduced, sinks down through the fuel, and collects at the bottom of the furnace. More ore and fuel are supplied above, and the operation goes on, till the melted metal, increasing in quantity, rises almost to the aperture of the blast; a passage is then made for it at the side of the furnace, and it is run into what is called pigs of cast iron. A furnace will furnish daily from two to five tons of iron, according to the richness of the ore, and the skill with which the operation is conducted. Ores of iron are combined with magnesia, are very refractory, and, as well as those which contain sulphur and arsenic, require to be roasted before they are cast into the smelting furnace.

Pig-iron is of very different qualities; that which is called No. 1, and the fracture of which is of a dark colour, runs so fluid as to be admirably suited for grates, and ornamental work. Cast-iron cutlery is manufactured

from it, as no other would run fine enough for the purposes to which it is applied, such as forks and small scissors, fish-hooks and needles. These articles obtain, by anealing, a considerable degree of malleability, and are even capable of being welded. When great strength is required, as for large wheels, beams, pillars, or rail-ways, the iron which contains a smaller proportion of carbon is preferable; as that called No. 2. The proportion of carbon in cast iron varies, in the different sorts, from one-fifteenth to one twenty-fifth. Cast iron also frequently contains a portion of the phosphuret of iron; in which case, it breaks of a white colour, and must, from its excessive hardness, be rejected for purposes which require it to be filed, or turned, or cut with the chisel. It may be observed, that the whiter the metal is, the harder it is, also; whether these properties are owing to its quality, or the mode of its management.

Crude or cast iron is converted into wrought iron, by keeping it in a state of fusion for a considerable time, and repeatedly stirring it in the furnace; the oxygen and carbon which it contains, unite, and fly off in a state of carbonic acid gas, and as this takes place the iron becomes more infusible; it gets thick or stiff in the furnace; and the workmen know, by this appearance, that it is time to submit it to the repeated action of the hammer, or the regular pressure of large steel rollers, by which the parts which still partake of the nature of crude iron so much as to retain the fluid state, are forced out, and the metal is rendered malleable, ductile, more closely compacted, of a fibrous texture, and totally infusible. In this state it is known in commerce by the name of bar iron. The loss of weight sustained by iron, in the process of refining, is considerable, generally amounting to one-fourth, and sometimes to one-half.

Forged, like cast iron, varies greatly in its quality. Thus some of it is tough and malleable when it is hot and when it is cold. This is the iron in common use, and it is the best, and most useful. It may be known generally by the equable surface of the forged bar, which

is free from transverse fissures, or cracks in the edges, and by a clear white, small grained, or rather fibrous texture. The best and toughest iron is that which has the most fibrous texture, and is of a clear greyish colour. This fibrous appearance is given by the resistance which its particles make to separation. The texture of the next best iron, which is also malleable in all temperatures, consists of clear whitish small grains, intermixed with fibres. Another kind is tough when it is heated, but brittle when cold. This is called cold-short-iron, and is distinguished by a texture consisting of large shining plates, without any fibres. It is less liable to rust than any other description of forged iron. A fourth kind of iron called hot-short, is extremely brittle when hot, and malleable when cold. On the surface and edges of the bars of this kind of iron, transverse cracks or fissures may be seen, and its internal colour is dull and dark.

The quality of iron may be much improved by violent compression, as by forging and rolling, especially when it is not long exposed to violent heat, which injures and at length destroys its metallic properties. But though iron is rendered malleable by hammering, this operation may be continued so long as to deprive it of its malleability.

Steel is made of the purest malleable iron, by a process called cementation. In this operation, layers of bars of malleable iron, and layers of charcoal, are placed one upon another, in a proper furnace, the air is excluded, the fire raised to a considerable degree of intensity, and kept up for 8 or 10 days. If, upon the trial of a bar, the whole substance is converted into steel, the fire is extinguished, and the whole is left to cool for 6 or 8 days longer. Iron thus prepared is called blistered steel, from the blisters which appear on its surface. In England, charcoal alone is used for this purpose; but Duamel found an advantage in using from one-fourth to one-third of wood-ashes, especially when the iron was not of so good a quality as to afford steel possessing tenacity of body as well as hardness. These ashes prevent the steel-making process from being effected so rapidly as it

would otherwise be, and give the steel pliability without diminishing its hardness. The blisters on the surface of the steel, under this management, are smaller and more numerous. He also found that if the bars, when they are put into the furnace, be sprinkled with sea salt, this ingredient contributes to give body to the steel. If the cementation be continued too long, the steel becomes porous, brittle, of a darker fracture, more fusible, and capable of being welded. On the contrary, steel cemented with earthy infusible powders is gradually reduced to the state of forged iron again. Excessive or repeated heating in the forge is attended with the same effect.

The properties of iron are remarkably changed by cementation, and it acquires a small addition to its weight, which consists of the carbon it has absorbed from the charcoal, and mounts to about the hundred-and-fiftieth, or two-hundreth part. It is much more brittle and fusible than before; and it may still be welded like bar-iron, if it has not been fused or over-cemented; but by far the most important alteration in its properties is, that it can be hardened or softened at pleasure. If it be made red-hot, and instantly cooled, it attains a degree of hardness which is sufficient to cut almost any other substance; but, if heated and cooled gradually, it becomes nearly as soft as pure iron, and may, with much the same facility, be manufactured into any determined form. A rod of good steel, in its hardest state, possesses so little tenacity, that it may be broken almost as easily as a rod of glass, of the same dimensions. This brittleness can only be diminished by diminishing its hardness; and in the proper management of this point, for different purposes, consists the art of tempering. The colours which necessarily appear on the surface of the steel, slowly heated, are yellowish-white, yellow, or straw colour, gold colour, brown, purple, violet, and deep blue. These signs direct the artist in reducing the hardness of steel to any particular standard. If steel be too hard, it will not be proper for tools which are intended to have a fine edge, because it will be so brittle, that the edge

will soon become notched: if, on the contrary, it be too soft, it is evident that the edge will turn or bend. Some artists inclose the tools to be hardened in an iron case or box, and slowly heat them to ignition; they then take the box out of the fire, and drop the pieces into water, in such a manner as will allow them to come as little as possible into contact with the air. This method answers two good purposes; it causes the heat to be more equally applied, and prevents the scaling occasioned by the contact of air. When the work has been polished, and well defended from the air, it is, when hardened, nearly as clear as before. If the tool be unpolished, they brighten its surface upon a stone. It is then laid upon burning charcoal, or upon the surface of melted lead, or upon an ignited bar or plate of iron, till it appears the desired colour; at which instant, they plunge it into cold water. The yellowish-white indicates a temper so little reduced as to be used for edge-tools; the yellow, or straw colour, the gold colour, and the brown, are used for penknives, razors, and gravers; the purple, for tools used in working upon metals, especially iron; the violet, for springs, and for instruments for cutting soft substances, such as cork, leather, and the like; but if the last blue be waited for, the hardness of the steel will scarcely exceed that of iron. When soft steel is heated to any of these colours, and then plunged into water, it does not acquire nearly so great a degree of hardness as if previously made quite hard, and then reduced by tempering. The degree of ignition required to harden steel is of different kinds. The best kinds require only a low red heat. It has been ingeniously supposed, that the hardness of steel depends on the intimate combination of its carbon; and, on this supposition, it follows, that the heat which effects this is the best, and that a higher degree will be injurious.

The texture of steel is rendered uniform by fusion. When it has undergone this operation, it is called cast-steel; which is wrought with more difficulty than common steel, because it is more fusible, and is dispersed

under the hammer, if heated to a white heat. The cast steel of England is made from the fragments of the crude steel of the manufactories and steel works. A crucible, about ten inches high and seven inches in diameter, is filled with the fragments, and placed in a wind furnace, like that of the foundries, but smaller, because intended to contain one pot only. It is, likewise, furnished with a cover and chimney, to increase the draught of the air. The furnace is entirely filled with coke, and five hours are required for the perfect fusion of the steel. It is then cast into ingots, and afterwards forged in the same manner as other steel, but with less heat and more precaution, as it is more liable to break. Cast steel is becoming more and more in use, but must necessarily be excluded from many works of considerable size, on account of the difficulty of welding it, and the facility with which it is degraded in the fire. Cast steel takes a fine firm edge, and receiving an exquisite polish, of which no other sort of steel is, in so high a degree, susceptible, it is made use of for all the finest cutlery in England; it is too imperfectly fluid to be cast into small wires. The tenacity of steel hammered at a low heat, or even when cold, is considerably increased; but the effect of the hammering is taken off by strong ignition. Tools, therefore, made of cast steel, and intended to sustain a good edge, for cutting iron and other metals, are not afterwards softened, but the ignition is carefully regulated at first, as the most useful hardness is produced by that degree of heat which is just sufficient to effect the purpose. Cast steel, annealed to a straw colour, is softened nearly as much as other kinds to a purple or blue.

Various methods of hardening steel are resorted to, such as oil, tallow, urine, and other saline liquids; soap in solution produces a similar effect. But when steel is required to possess the greatest degree of hardness, it may be quenched in mercury, which will render it so hard as to cut glass like a diamond.

Wrought iron may be hardened, in a small degree, by

ignition and plunging into water, but the effect is confined to the surface; except, as very often happens, the iron contains veins of steel.

The surest method for selecting steel for edge tools, is, to have one end of the bar drawn out under a low heat, such as an obscure red, and then to plunge it suddenly, at this heat, into a pure cold water. If it prove hard, for instance, if it will easily cut glass, and require a great force to break it, whatever its fracture may be, it is good, the excellence of steel being always proportionate to the degree of its tenacity in its hard state: in general a neat curved line fracture, and even grey texture, denote good steel, and the appearance of threads, cracks, or brilliant specks, is a proof of the contrary.

If diluted nitrous acid (aquafortis) be applied to the surface of steel previously brightened, it immediately produces a black spot, but if applied to iron, in like manner, the metal remains clear. By this method it will be easy to select such pieces of iron or steel as possess the greatest degree of uniformity; as the smallest vein of either upon the surface, will be distinguished by its peculiar sign.

The hardness and polish of steel may be united, in a certain degree, with the firmness and cheapness of malleable iron, by what is called *case-hardening*, an operation much practised, and of considerable use. It is a superficial conversion of iron into steel, and only differs from cementation in being carried on for a shorter time: some artists pretend to great secrets in the practice of this art, using saltpetre, sal ammoniac, and other fanciful ingredients, to which they attribute their success. But it is now an established fact, that the greatest effect may be produced by a perfectly tight box, and animal carbon alone.

The goods intended to be case-hardened, being previously finished with the exception of polishing, are stratified with animal carbon, and the box containing them luted with equal parts of sand and clay. They are then placed in the fire, and kept in a light-red heat

for half an hour, when the contents of the box are emptied into water. Delicate articles may be preserved like files, by a saturated solution of common salt with any vegetable mucilage to give it a pulpy consistence. The carbon here spoken of, is nothing more than any animal matter, such as horns, hoofs, skins, or leather, just sufficiently burnt to admit of being burnt to powder. The box is commonly made of iron, but the use of it, for occasional case-hardening upon a small scale may be easily dispensed with; as it will answer the same end to envelope the articles with the composition above directed to be used as a lute, drying it gradually, before it is exposed to a red heat, otherwise it will probably crack. It is easy to infer, that the depth of the steel induced by case-hardening, will vary with the time the operation is continued. In half an hour it will scarcely be the thickness of a six-cent piece, and therefore will be removed by the violent abrasion, though sufficient to answer well for fire-irons, &c., in the common usage of which its hardness prevents its being easily scratched, and its polish is preserved by friction with so soft a material as leather.

The *blueing* of steel has a remarkable influence on its elasticity. This operation consists in exposing steel, the surface of which has been brightened, to the regulated heat of a plate of metal, or of a fire, or lamp, till the surface has acquired a blue colour. If this blue colour, so commonly considered rather as ornamental than useful, be partially or wholly removed, by grinding, or in any other manner, the elasticity is proportionately impaired, and the original excellence of this property can only be restored by blueing the steel again. Sawmakers first harden their plates in the usual way, in which state they are brittle and warped; they then soften them by blazing, which consists in smearing the plate with oil or grease, and heating it till thick vapours are emitted, and burn off with a blaze. They then hammer them flat, and afterwards blue them on a hot iron, which renders them stiff and elastic, without altering their flatness.

Steel expands its dimensions, in a small degree, by hardening. It is a curious fact, that intense cold has an unfavourable effect on steel; so that, in severe frosts, workmen often find their tools incapable of receiving the temper they wish.

A slender rod of wrought iron may be expeditiously converted into steel, by plunging it into cast iron in fusion; a satisfactory proof that cast iron contains the steel-making principle, which, we need not repeat, is carbon. In fact, as it is principally in the superabundance of its carbon that it differs from steel, many attempts, (and not without success,) have been made to convert it into the latter, without the intermediate operation of rendering it malleable. But the best steel made pursuant to this idea, is very imperfect. It is, however, not unimportant to observe, that all cast iron so far resembles steel, as to be hardened in a high degree by sudden cooling, which imparts to it, at the same time, whiteness of colour, brittleness, and closeness of texture. This property of crude iron may be advantageously employed on many occasions; for instance, in the fabrication of axles, and collars of wheels, which are closely turned or filed in a thin soft state, and may afterwards be hardened, so as to wear admirably well.

The heat applied to cast iron, previously to its being plunged into the water to harden, is greater than that to which steel is subjected for the same purpose. Cast iron, also, when once hardened, admits not, like steel, of that hardness being reduced, by various gradations, to any specific degree; to soften it materially, it must be submitted, for some time, to a complete ignition, and very gradually cooled.

ANEALING.

In a considerable number of instances, bodies which are capable of undergoing ignition, are rendered hard and brittle by sudden cooling. Glass, cast iron, and steel, are the most remarkably affected by this circumstance; the inconveniences arising from which are obviated by

cooling them very gradually, and this process is called annealing. Glass vessels are carried into an oven over the great furnace called the leer, where they are permitted to cool, in a greater or less time, according to their thickness and bulk. Steel is most effectually anealed by making it red-hot in a charcoal fire, which must completely cover it, and be allowed to go out of its own accord. Cast iron, which may require to be annealed in too large a quantity, to render the expense of charcoal very agreeable, may be heated in a cinder fire, which must completely envelope and defend the pieces from the air till they are cold. The fire need not be urged so as to produce more than a red heat; a little beyond this, bars and thin pieces would bend, if destitute of a solid support; and would even be melted without any vehement degree of heat. If it be required to aneal a number of pieces expeditiously, and the fire is not large enough to take more than one or two of them at once; or if it be thought hazardous to leave the fire to itself, from an apprehension that the heat might increase too much, the following scheme may be adopted: heat as many of the pieces at once as may be convenient, and as soon as they are red-hot, bury them in the dry sawdust. Cast iron, when anealed, is less liable to warp by a subsequent partial exposure to moderate degrees of heat, than that which has not undergone this operation.

The above methods of anealing render cast iron easy to work, but do not deprive it of its natural character Cast iron cutlery is, therefore, stratified with some substance containing oxygen, such as poor iron ores, free from sulphur, and kept in a state little short of fusion for twenty-four hours. It is then found to possess a considerable degree of malleability, and is not unfit for several sorts of nails and edge-tools.

Copper forms a remarkable exception to the general rule of anealing. This metal is actually made softer and more flexible by plunging it, when red-hot, into cold water, than by any other means. Gradual cooling produces a contrary effect.

COPPER.

We refer to the article of chemistry for a minute enumeration of the whole of the known metals; but in this place, we shall, with the exception of iron, which has already been noticed, introduce a general practical view of the properties, applications, and combinations with each other, of those most frequently occurring in common arts and common life. Making this our plan, the first object that claims our attention is copper.

Copper is a very brilliant, sonorous metal, of a fine colour, possessing a considerable degree of hardness and elasticity. It is extremely malleable, and may be reduced to leaves so fine, that they may be carried about by the wind. Its tenacity is very great. A wire of one-tenth of an inch in diameter will support a weight equal to 300 lbs. avoirdupois, without breaking. It does not melt till the temperature is elevated to about 27° of Wedgwood; or, (by estimation) 14.50° of Fahrenheit. When rapidly cooled, it exhibits a granulated and porous texture. When the texture is raised beyond what is necessary for its fusion, it is sublimed in the form of visible fumes. Its greatest malleability is at a low red heat. None of the malleable metals are so difficult to file, or turn smooth, as copper; but it is cut by the graver, or ground by gritty substances, with great ease.

When miners wish to know whether an ore contains copper, they drop a little nitric acid upon it; after a little time, they drop a feather into the acid, and wipe it over the polished blade of a knife; if there be the smallest quantity of copper in it, this metal will be precipitated upon the knife, to which it will impart a peculiar colour. Roman vitriol, much used by dyers, and in many of the arts, is a sulphate of copper. A solution of this salt is used for browning fowling-pieces and tea-urns. In domestic economy, the necessity of keeping copper vessels perfectly clean, cannot be too strongly inculcated but it is worthy of remark that fat and oily substances, and vegetable acids, do not attack copper while hot; and,

therefore, copper vessels may be used, for culinary purposes, with perfect safety, if no liquor be ever suffered to grow cold in them. The mere tinning of copper and brass vessels does not afford complete safety, as it is never so perfect as to cover every part.

Compounds formed by the mixture of two or more different metals are called alloys. The alloys of copper, especially those in which this metal predominates, are more numerous in the arts than those of any other metal. Many of them are perfectly well known, and have been immemorially in use. The exact composition, and particularly the mode of preparing several, are kept as secret as possible. By the aid of chemistry, we may detect the exact composition of an alloy; yet we may not always be able, by common methods, to produce a mixture having all the excellencies, which perhaps, mere accident has taught the possessor of the secret to combine.

Brass is the most important of all the alloys of copper. It is more fusible than copper, less liable to tarnish from exposure to the atmosphere, and its fine yellow colour is more agreeable to the eye. It is much more malleable than copper, when cold, but less malleable when hot; at a low red heat, it crumbles under the hammer. Sieves of extreme fineness are woven with brass wire, after the manner of cambric weaving which could not possibly be made with copper wire. Three parts of copper and one of calamine, or native carbonate of zinc, constitute brass. The calamine is first pounded in a stamping mill, and then washed and sifted, in order to separate the lead with which it is mixed. It is then calcined on a broad, shallow brick earth, over an oven heated to redness, and frequently stewed for some hours. In some places, it is calcined in a kind of kiln, filled with alternate layers of calamine and charcoal, and kindled from the bottom, where a sufficient quantity of wood has been deposited for the purpose. When the calamine has been thoroughly calcined, it is ground in a mill, and mixed at the same time with a third or a fourth part of charcoal, and is

then ready for the brass furnace. Being put into crucibles with the requisite proportion of grain copper copper chippings, or refuse bits of various kinds, the whole is covered with charcoal, and the crucibles luted up with a mixture of clay or loam and horse-dung. The heat employed, is, for a considerable time, not sufficient to melt the copper, which is at length raised so as to fuse, and the compound metal is then run into ingots.

In general, the extremes of the highest and lowest proportions of zinc are from twelve to twenty-five per cent. of zinc; brass is perfectly malleable, if well manufactured, though zinc itself scarcely yields to the hammer at common temperatures.

Good brass, when received from the foundry, is nearly inelastic, but exceedingly flexible, and when polished, the naked eye cannot discover any pores, which are frequently observable in the inferior kinds. The liberal use of the hammer imparts a considerable portion of elasticity to brass, and renders it at the same time less flexible. Clock-makers, watch-makers, and all artists who employ this metal, put it in forms that admit of hammering it well before they turn or file it; otherwise their work would wear indifferently, and a trifling cause injure its figure. Brass is not malleable when ignited.

Hammering is found to give a magnetic property to brass, perhaps occasioned by the minute particles of iron separated from the hammer and the anvil during the process, and forced into its surface. This circumstance makes it necessary to employ unhammered brass for compass boxes and similar apparatus.

Five or six parts of copper and one of zinc, form a pinchbeck. Tombac has still more copper, and is of a deeper red than pinchbeck. Prince's metal is a similar compound, excepting that it contains more zinc than either of the former.

The alloys of copper with different proportions of tin, are of great importance in the arts. They form compounds which have distinct and appropriate uses. Tin renders copper more fusible, less liable to rust, harder,

denser, and more sonorous. Copper and tin separately, are not more remarkable for their ductility, than, when united, the compounds they form are for their brittleness.

Eight to ten parts of tin, combined with one hundred parts of copper, form bronze, which is of a greyish yellow colour, harder than copper, and the usual composition for statues.

The customary proportions for bell-metal are, three parts of copper and one of tin. The greater part of the tin may be separated by melting the alloy, and then throwing a little water upon it. The tin decomposes the water, is oxidized, and thrown upon the surface. The proportion of tin in bell-metal is varied a little at different foundries, and for different sorts of bells. Less tin is used for large bells than smaller ones, and for very small ones, a trifling quantity of zinc is used, which renders the composition more sonorous, and it is still further improved in this respect by a little silver being added.

A small quantity of antimony is occasionally found in bell-metal. When copper, brass, and tin, are used to form bell-metal, the copper is from seventy to eighty per cent. including the proportion contained in the brass, and the remainder is tin and zinc. When tin is nearly one-third of the alloy, it is then beautifully white, with a lustre almost like mercury, extremely hard, close-grained, and brittle; but when the proportion of tin is one-half, it possesses these properties in a still more remarkable degree, and is susceptible of so exquisite a polish, as to be admirably adapted for the speculums of telescopes. If more tin be added than amounts to half the weight of the copper, the alloy begins to lose that splendid whiteness for which it is so valuable as a mirror, and becomes of a blue grey. As the quantity of tin is increased, the texture becomes rough-grained, and totally unfit for manufacture.

OF TIN.

Tin is a metal of considerable importance in the arts. It is of a silver-white colour, very ductile, malleable, and

gives out while bending, a peculiar crackling noise. Its specific gravity is 7.291; a cubic foot weighs about 516 lbs. avordupois. Its purity is in proportion to its levity. It melts at the 400th degree of Fahrenheit's thermometer, and promotes the fusibility of the metals with which it is mixed. Two parts lead and one of tin form plumbers' solder, which melts sooner than either of the metals separately. Eight parts of bismuth, five of lead, and three of tin, form a metal which melts at a heat not exceeding that of boiling water.

Tin is used to form boilers for dyers, and worms for rectifiers' stills. The common mixture for pewter is 112 lbs. of tin, 15 lbs. of lead, and 6 lbs. of brass. But the name of pewter is given to any malleable white alloy into which tin largely enters; and perhaps no two manufacturers employ the same ingredients in the same proportions. The finest kinds of pewter contain no lead whatever; but consist of tin, with a small quantity of antimony, and sometimes, a little copper. Pewter may be used for vessels containing wine, and even vinegar, provided the tin constitutes three-fifths of the alloy.

The consumption of tin, in the operation called tinning, is very considerable. The principal secret in tinning is, to preserve the tin and surface of the metal to which it is intended to be applied, perfectly clean, and in a pure metallic state. Thin plates or sheets of iron, which, when coated with tin, are so well known under the name of tin-plates, white iron, or latten, are prepared by scouring them with sand. They are then immersed in water, acidulated with sulphuric acid, in which they are kept for twenty-four hours, being occasionally turned during that time, so that they may rust equally in every part. When taken out, they are scoured, and made perfectly clean; they are then dipped in pure water, and kept till wanted for tinning. The tin is melted in an iron crucible, narrow, but deeper than the length of the iron plates, which are plunged in downright, so that the tin swims over them. The surface of the tin, to prevent its oxidation, is covered with some oily or resinous matter.

Reaumur states, that the Germans cover it with suet, previously prepared by frying and burning, which surprisingly puts the iron in a condition to receive the tin. The melted tin must also have a certain degree of heat. If not hot enough, it will not adhere to the iron; and, if it be too hot, the coat will be very thin, and the plates discoloured. Plates intended to have a very thick coat, are first dipped into the crucible when the tin is very hot, and afterwards, when it is cooler. For the second dipping, the suet must not be prepared, but used in its common state. The tin not only adheres to the surface of iron plates, but penetrates, and intimately combines with them.

Copper is tinned after it has been formed into utensils. If the copper be new, its surface is first scoured with salt and diluted sulphuric acid; pulverised resin is then thrown over the interior of the vessel, into which, after heating it to a considerable degree, a sufficient quantity of melted tin is poured, and spread upon it, by means of a rod of hard-twisted flax; which renders the coating uniform. Pure tin is rarely used for this purpose; it is generally, though injuriously, alloyed with a small proportion of lead. The use of the resin is important; for the heat given to the copper is sufficient to oxidize its surface in some degree; and an alteration of this sort, however slight, would prevent the perfect adhesion of the tin. The resin is equally useful in preventing the partial oxidation of the tin, or in reviving the small particles of oxide which may be formed during the operation.

For tinning old vessels a second time, the surface is first scraped clean and bright with a steel instrument, or scoured with iron scales, then pulverised salammoniac is strewed over it, and the melted tin is rubbed on the surface with a solid piece of salammoniac.

The process for covering iron vessels with tin, corresponds with that last described; but they ought to be previously cleaned with the muriatic acid, instead of being scraped or scoured. Iron nails which cannot be

conveniently tinned in a bath, are easily covered with tin by including them, with a due proportion of tin and salammoniac, in a stone bottle, and agitating them while heating and cooling.

The following method of tinning is highly esteemed for its permanency and beauty: the utensil is cleaned in the usual manner; its inner surface is beaten on a rough anvil, or scratched with a wire-brush, that the tinning may adhere more closely to the copper; and one coat of fine tin is then laid on with salammoniac as above directed for tinning old copper. A second coat consisting of two parts of tin and three of zinc, must next be uniformly applied with salammoniac, in a similar manner: the surface is now to be beaten; scoured with chalk and water; smoothed with a proper hammer; exposed to a moderate heat; and lastly dipped in melted tin. This sort of tinning effectually prevents the utensils from rusting.

Pins are whitened by filling a pan with alternate layers of them and grain-tin. A solution of super-tartrate of potass, (cream of tartar) is then poured upon them, and they are boiled for four or five hours. The tartaric acid first dissolves the tin, and then gradually deposits it on the surface of the pins, in consequence of its greater affinity for the zinc which enters into the composition of the brass wire.

There are two kinds of tin known in commerce; viz. *block tin*, and *grain tin*. Block tin is procured from the common tin ore; grain tin is found, in small particles, in what is called stream tin ore. It owes its superiority not only to the purity of the ore, but to the care with which it is washed and refined.

OF LEAD.

Lead unites with most of the metals. It has little elasticity, and is the softest of them all. Gold and silver are dissolved by it in a slight red heat; but, when the heat is much increased, the lead separates, and rises to the surface of the gold, combined with all heterogeneous

matters. This property of lead is made use of in the art of refining the precious metals.

If lead be heated so as to boil and smoke, it soon dissolves pieces of copper thrown into it: the mixture, when cold, is brittle. The union of these two metals is remarkably slight; for, upon exposing the mass to a heat no greater than that in which lead melts, the lead almost entirely runs off by itself. This process, which is peculiar to lead with copper, is called eliquation. It has lately been discovered, that a certain preparation of lead may be mixed with the metal formerly used for white metal buttons, without injuring the appearance; thus affording a considerable addition of profit to the manufacturer.

The consumption of lead for water-pipes, cisterns, and to cover buildings, is very extensive. Sheet-lead is made by suffering the melted metal to run out of a box through a long horizontal slit, upon a table prepared for the purpose. The table is generally covered with sand, and the box is drawn over it by appropriate ropes and pulleys, leaving the melted lead behind, to congeal in the desired form. The requisite uniformity and thinness are given to these sheets, by rolling them between two cylinders of iron, acting upon the same principle as the copper-plate printing-press.

The alloy of lead and antimony is used for printers' types. Chaptal made a great variety of experiments to ascertain the best proportions of these metals to each other for this use. He always found four parts of lead and one of antimony form the most perfect composition. But, if the antimony be pure, one part of it, to seven or eight of lead, form an alloy too brittle to be extended under the hammer, and as hard as the generality of types. To give hardness to the lead, is not the only use of antimony in this composition. It renders the lead more fusible, more fluid when melted, and, as it expands in passing to a solid state, it is calculated to produce a sharper impression of the mould than could be easily obtained by lead alone. Antimony, (which in trade is

sometimes called regulus of antimony, or regulus, only,) requires, when alone, much more heat for its fusion than lead, in combining with which metal, as it is little more than half its weight, it rises to the surface, and requires to be well stirred before it will incorporate. Different parts of the same block of type-metal often possess different degrees of hardness. In melting lead for shot, a small quantity of arsenic is added, to cause it to run into spherical drops. The arsenic is generally added in excess to a small quantity of lead, which is covered and closely luted till the incorporation is complete. The compound is called slag, or poisoned metal. Ingots of this slag are then added to soft pig-lead, in such proportion as is found, upon trial, to cause it to drop in a globular form.

The surface of melted lead, as every one knows, becomes quickly covered with a skin or pellicle, often assuming different lively hues at first, and subsequently increasing in quantity and darkness of colour. This effect is termed by chemists, oxidation, as it is occasioned by the action of oxygen of the atmosphere, the activity of which is greater in proportion to the heat of the lead, and wastes the metal so fast, that it becomes an object of importance to those who melt much lead, to check its formation, or to convert it, when formed, by the cheapest process into the metallic state again. A thick coating of ashes of any kind will check the formation of the oxide, and may be easily pushed back, when a quantity of lead must be taken out of the crucible or melting-pan. Charcoal, which is also a good covering for lead in the pan, will convert dross into metal, when assisted by a sufficient heat; fat, oily, and bituminous substances in general, have a similar effect. Common resin answers exceeding well; thrown in powder upon melted lead, and stirred about, it immediately converts the oxide into metal, causes the surface to shine like mercury, and if any thing remains, it is only a black dirt, with small globules of pure lead, skimmed off at the same time, yet mixed with it; by throwing it into water, stirring it thoroughly

and pouring off all that does not immediately sink, these grains may be separated. If part of what appears to be dirt, is found to be so heavy, as instantly to sink to the bottom of water, it may be suspected to be true dross or oxide, and may be revived by mixing it with charcoal, and exposing it to a considerable heat. It is always, however, more prudent and economical to use means of preventing the formation of oxide, than to bestow much time upon its revival.

Lead becomes less fluid every time it is melted, and by much or frequent exposure to a high temperature, a state in which it is said to be rotten, is superinduced. To use new lead, and not melt it oftener, or expose it to a greater heat than is indispensable, are necessary precautions to preserve this metal in its best state. Plumbers, when they cast it into sheets, strew common salt upon the table, to facilitate its spreading, when they are not using new lead, and are for that, or any other reason, apprehensive that it will not run well.

The observations above recited on the management of lead, apply with equal propriety, to tin, antimony, zinc, bismuth, &c., and all the alloys of these metals with lead or each other. In fact, as lead is so much cheaper than the other metals just enumerated, the object of saving it from destruction is proportionately of less consequence.

OF ZINC.

Zinc is a very combustible metal, of a bluish, brilliant white colour. It seems to form the link between the brittle and the malleable metals. It is a modern discovery, that at a temperature of from 210° to 300° of Fahrenheit, it yields to the hammer, may be drawn into wire, or extended into sheets. After having been thus annealed, it continues soft, flexible, and extensible, and does not return to its partial brittleness; thus admitting of being applied to many uses for which zinc was formerly deemed unfit.

There can now be no difficulty in forming zinc into

sheathing for the bottoms of ships, into vessels of capacity, water pipes, and utensils for various manufactories. As an internal lining for ordinary vessels, instead of tin, it has been applied with success. It is much harder and cheaper than tin, and may be spread very uniformly.

Zinc at a very elevated temperature, may be pulverized. It may also, like several other metals, be minutely divided, by pouring it, when in fusion, into water. These are the most convenient means of reducing it into small particles. Files have no considerable action upon it; besides, it wears and chokes them up in a short time. Zinc, in filings or small particles, is used to produce those brilliant stars and spangles which are seen in the best artificial fire-works; but the filings of cast iron produce, at a cheaper rate, an effect scarcely inferior.

Calamine, or lapis calaminarus, used in converting copper into brass, is found in masses and in a crystallized state, and is generally combined with a large portion of silex. It is a native oxide of zinc, combined with carbonic acid. Zinc is also found in an ore called *blena*, or as the miners term it, Black Jack. It is a sulphuret of zinc: in Wales, it was employed formerly in mending the roads.

SOLDERING.

To unite two pieces of the same or different metals, by fusing some metallic substance upon them, is called *soldering*. It is a general rule, that the solder should be easier of fusion than the metal to be soldered by it. It is, in the next place, desirable, though seldom absolutely necessary, nor always attempted, that the solder and the metal to which it is intended to be applied, should be of the same colour, and of the same degree of hardness and malleability.

Solders are distinguished into two different classes, viz. the hard and the soft solders. For the hard solders, which are ductile, and admit of being hammered, some of the same sort of metal as that to be soldered, is, in the greatest number of instances, alloyed with some

other which increases its fusibility. Some of the facts already detailed, respecting the metals, prove that the addition made with this view need not always be itself easier of fusion.

The solder for platina is gold, and the expense of it will, therefore, contribute to hinder the general use of platina vessels, even in chemical experiments.

The hard solder for gold, is composed of gold and silver: gold and copper; or gold, silver, and copper. Goldsmiths usually make four kinds, viz. solder of eight, in which, to seven parts of silver, there is one of brass or copper; solder of six, where only a sixth part is copper; solder of four, and solder of three. But many who may have occasion to solder gold, cannot encumber themselves with these varieties.

For general purposes, therefore, the following composition may be provided; melt two parts of gold, with one of silver and one of copper; stir the mass well to make it uniform, add a little borax in powder, and pour it out immediately. If cast into very thin narrow slips, it will be the more handy for subsequent use. To cleanse gold which has been soldered, heat it almost to ignition, let it cool, and then boil it in urine and sal ammoniac.

The hard solder for silver may be prepared by melting two parts of silver with one of brass. It must not be kept long in fusion, lest the zinc of the brass fly off in fumes. If the silver to be soldered, be alloyed with much copper, the proportion of brass may be increased: for example, the following composition may be used; four parts of silver and three of brass, rendered easy of fusion by a sixteenth part of zinc. Silver which has been soldered, may be cleaned by heating it, and letting it cool, as directed for gold, but it must be boiled in alum water.

The hard solder for copper and brass, is a soft fusible sort of granulated brass, known to artists by the name of speltre. It consists of brass mixed with an eighth, or a sixth, or even one-half of zinc. The braziers use no other kind of hard solder. As speltre melts sooner than common brass, it serves for the solder of the latter as well as for copper.

Standard silver makes an excellent solder for brass. It is more fusible than speltre, proportionately easier to manage, and equally as durable. A slight demand for silver solder, may, to many, be supplied at a cheap rate, in consequence of the number of the small silver articles in use, and which are frequently wearing out.

Iron may be soldered with copper, gold, or silver Brass or speltre is most commonly used, and the operation is then called brazing; but a carbonate of the same metal, viz. the dark grey or most fusible sort of pig iron, called No. 1, is the most durable solder that can be used. The pig iron loses some brittleness, and the malleable metal becomes harder in the proximity of the parts soldered.

The parts upon which hard solder is intended to operate, are touched with a finely powdered borax moistened with water. They must, also, as in all soldering and tinning operations, be perfectly clean. The borax quickly running into a kind of glass, promotes the fusion of the solder, and preserves from oxidation the surfaces to which it is applied. The pieces intended to be soldered, are fastened together with iron wire, or secured by some contrivance having the same effect. Speltre being composed of so many grains, is apt to spread when the borax boils up; but just as it becomes fused, the workmen bring it to the place where it is wanted, by a slender iron rod. The flame of a lamp, directed by a blow-pipe against the solder covering the intended joint, which must be laid upon charcoal, is sufficient for small things. For large work, a common culinary fire may be made to effect the desired fusion, though a forge is still more convenient. The fire should not touch the work, nor the ashes be allowed to fall upon it.

The soft solders melt easily, but are partly brittle, and therefore cannot be hammered. The solder for lead is usually composed of two parts of lead and one of tin. Its goodness is tried by melting it, and pouring about the size of a crown-piece upon a table; little shining stars will arise upon it, if it is good. By diminishing the

proportion of lead, we form what is called stray solder: we may also increase the proportion, which is advisable when we wish to solder vessels for containing acids· because lead is not so easily corroded or dissolved as tin.

The lining of tea-chests has been used for solder, as it sometimes comes mixed about the right proportion. These valuable portions of tea-lead may be distinguished by their brilliancy, having suffered little from oxidation; also, when they principally consist of tin, by the crackling noise while bending; which is peculiar to this metal, and some of the alloys into which it largely enters.

The solder for tin may consist of four parts of pewter, one of tin, and one of bismuth, or two parts of tin, and one of lead: the latter is a composition much used.

The soldering-iron of the tin-plate workers is an ingot of copper, flattened at the point, in a pyramidal form: it is screwed or riveted to an iron stem fastened to a wooden handle. The copper is seldom more than four or five inches long, and when it is worn away, the same stem and handle are used for another piece. The bar of copper is prepared for use, by filing it bright, and tinning it; when sufficiently hot, it will melt and take up the solder, so as to afford a ready means of applying it to the intended juncture. Powdered rosin, and sometimes pitch, is used along with the soft solders, to preserve the metals employed from oxidation.

Tin-foil, applied between the joints of fine brass-work, first wetted with a solution of sal ammoniac, and held firmly together while heated, makes an excellent juncture, care being taken to avoid too much heat.

OF GLUE.

To prepare glue, it must be steeped for a number of hours, over night, for instance, in cold water, by which means it will become considerably swelled and softened. It must then be gently boiled, till it is entirely dissolved, and of a consistence not too thick to be easily brushed over wood. About a quart of water may be used to

half a pound of glue. The heat employed in melting glue should not be more than is required to make water boil; and to avoid burning it, the workmen, as is well known, suspend the vessel containing it in another vessel containing only water, which latter vessel is made in the form of a common tea-kettle without a spout, and alone receives the direct action of the fire.

The circumstances most favourable to the best effects which glue can produce, in uniting two pieces of wood, are the following: that the glue should be thoroughly dissolved, and used boiling hot at the first or second melting; that the wood should be warm and perfectly dry; and a very thin covering of glue be interposed at the juncture, and that the surfaces to be united, be strongly pressed together, and left in that state, in a warm but not hot situation, till the glue be completely hard. In veneering, and for very delicate work, the whole of these requisites, as they not only ensure the strongest, but the glue sets the soonest, should be combined in the operation; but on some occasions this is impossible, and, therefore, the most essential must be regarded, such as the fitness of the glue, and dryness of the wood. When the faces of joints, particularly those that cannot be much compressed, have been besmeared with glue, which should always be done with the greatest expedition, they should be rubbed lengthwise one upon another, two or three times, to settle them close.

When glue, by repeatedly heating it, has become of a dark and almost black colour, its qualities are impaired; when newly melted, it is of a light ruddy brown colour, nearly like that of the dry cake held up to the light; and while this colour remains, it may be considered fit for almost every purpose. Though glue which has been melted is the most suitable for use, other circumstances being the same, yet that which has been the longest manufactured is the best. To try the goodness of glue, steep a piece three or four days in cold water; if it swell considerably without melting, and when taken out resumes, in a short time, its former dryness, it is excel-

lent. If it be soluble in cold water, it is a proof that it wants strength.

A glue which does not dissolve in water, may be obtained by melting a common glue with the smallest possible quantity of water, and adding by degrees linseed oil rendered drying by boiling it with litharge; while the oil is added, the ingredients must be well stirred to incorporate them thoroughly.

A glue which will resist water, in a considerable degree, is made by dissolving common glue in skimmed milk.

Finely lixiviated chalk added to the common solution of glue in water, constitutes an addition that strengthens it, and renders it suitable for boards, or other things which must stand the weather.

A glue that will hold against fire or water, may be prepared by mixing a handful of quick-lime with four ounces of linseed oil: thoroughly lixiviate the mixture, boil it to a good thickness, and then spread it on tin plates in the shade; it will become exceedingly hard, but may be dissolved over a fire, as ordinary glue, and is then fit for use.

THE COMMON SLIDING RULE.

The divisors inserted in the following table, and the few plain directions and examples given, will now render it capable of being applied to every purpose that any artificer can possibly want. And by taking a copy of the table upon a piece of parchment, and carrying it always in the pocket, these divisors will be at hand: and the weight or measure required may be obtained.

Description of the lines upon the slide rule.

Upon the sliding rule of this rule are four lines marked A, B, C, and D. The three marked A, B, and C are double lines of numbers, one of which is upon the rule, and the other two are upon the slide. That marked D is a single line of numbers, commonly called the girt line.

Numeration.

These four lines are divided as follows: each of the double lines marked A, B, and C are figured 1, 2, 3, 4, 5, 6, 7, 8, 9; then again 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 at the end. And these figures may be increased or decreased in the value, but always in a tenfold proportion, at pleasure; thus one at the beginning may be called either 1, or 10, or 100, or 1000, and then the one in the middle of the rule must be called 10, 100, 1000 or 10,000. Observe, from one to two is divided into 10 parts, and each tenth is subdivided into 5 parts, and from 2 to 3 is divided into ten parts, and each tenth into 2 parts, and from 3 to 4 and so on to 10 is divided into 10 parts only The girt line, marked D, is figured 4, 5, 6, 7, 8, 9, 10 12, 15, 20, 25, 30, 35, and 40 at the end.—And the figures and divisors are valued in tenfold proportion, as above.

As there have been so many books published for the use of this Rule, it is unnecessary to say much upon the subject; because when numeration is properly understood, any person, from these plain directions, may perform any operation, in superficial and solid mensurations, that may be wanted in the common course of business, and, with the assistance of these divisors, may find the weight of any of the articles contained in the table.

A TABLE OF DIVISORS

For the use of the common single Sliding Rule.

The first column contains the divisors for dimensions that are taken feet long, feet wide, and feet thick. The second column is for dimensions that are taken feet long, inches wide and thick. The third column is for dimensions that are taken inches long, inches wide, and inches thick.

The fourth is a column of divisors for dimensions that

are taken feet long, and inches diameter. The fifth column is for dimensions that are taken inches long and diameter.

The sixth is a column of divisors or diameters, taken in feet. The seventh column is for diameters taken in inches.

	Square.			Cylinders.		Globes.	
	1st.	2d.	3d.	4th.	5th.	6th.	7th.
Cubic Inches	36	518	624	660	799	625	113
Cubic Feet	625	9	108	114	138	119	206
Wine Gallons	835	12	145	153	183	16	276
Ale Gallons	102	147	176	188	224	196	335
Water in lb.	10	144	174	184	22	191	329
Oil in lb.	108	1565	189	199	238	207	358
Gold in lb.	507	735	88	96	118	939	180
Silver in lb.	938	136	157	173	208	173	354
Quicksilver in lb.	738	122	127	132	162	141	242
Brass lb.	12	174	207	221	265	23	397
Copper lb.	112	163	196	207	247	214	371
Lead lb.	880	126	152	162	194	169	289
Wrought Iron	120	186	222	235	283	247	423
Cast Iron and Speltre lb.	139	2	241	254	304	265	458
Tin lb.	137	135	235	25	300	261	454
Steel lb.	136	183	22	233	278	239	418
Marble lb.	370	53	637	725	81	72	121
Free-stone lb.	394	57	69	728	873	755	132
Brick lb.	495	72	860	92	10	95	164
Coal lb.	795	114	138	146	176	151	262
Dry Oak lb.	108	158	190	2	237	208	355
Mahogany lb.	94	136	164	175	208	18	336
Box lb.	968	152	169	194	214	186	32
Red Deal lb.	151	22	263	285	236	287	501

EXAMPLES.

Example 1. Required the content in cubic inches of a piece of timber 2 feet long, 12 inches wide, and 12 inches thick; see the preceding table of divisors in the line of cubic inches, second column, and you will find the divisor for feet long, inches wide, and inches thick is 518, set 2, which is the length upon B, to 518, the divi-

sor upon A, against 12, which is the breadth and thickness upon D, 3456, which is the content in inches on C.

Ex. 2. Having the dimensions of an unequal sided piece of timber given to find the mean square, which must be done in all cases where the breadth and thickness are unequal. What is the square of a piece of timber 16 inches broad, and four inches thick? Set 16, the breadth on C, to 16 on D, and against 4, the thickness on C is 8 inches the square on D.

Ex. 3. Required the content of a piece of cast iron 24 inches long and 12 square; see the preceding table in the line cast iron and speltre, third column, is divisor 241; set 24 on B to 241 on A, and against 12 on D is 896 on C.

Ex. 4. Required the weight of a piece of cast iron circular 24 inches and 12 diameter: see the preceding table, fifth column, in the line cast iron and speltre is 304 the divisor; set length on B to the divisor on A, and against the diameter on D is 708 lbs. the content on C.

Ex. 5. Required the weight of a ball or globe in cast iron 12 inches in diameter; see the preceding table, seventh column, in the line cast iron and speltre is 458, the divisor; set 12 the diameter on B to 458, the divisor on A, and against 12 inches diameter on D, is 235 the content on C.

Ex. 6. Required the content of a piece of timber 1 inch long and 12 inches diameter; see the preceding table, in the line cubic inches, fifth column, under cylinders, the divisor is 799; set 1 inch, the length on B, to 799 on A, and against 12 inches the diameter on D, is 113, the content on C. Observe, when the slide stands in this position it is a table of areas of all circles, D being diameters, or the squares of diameters, and C being areas or superficial inches.

Ex. 7. Required the content of a piece of land, 70 yards long, by 70 wide; set 4840 on A, the number of yards in an acre, to 70 the length on B, and against 70 the width on A is 1.01 on B.

Ex. 8. Required the content of a piece of land, 40

poles long, and 5 poles wide; set 160, the number of poles in an acre on A, to 40 the length on B, and against 5, the width on A is 1.25 or 1 acre on B.

Ex. 9. Required the diameter of a circle, whose area is equal an ellipsis or oval, 32 by 22 inches diameter set 32 on C, to 32 on D, and against 22 on C is 26.6 nearly on D.

Ex. 10. Required the side of a square, equal in proportion to a parallelogram or long square, 32 by 22 inches; set 32 on C to 32 on D, and against 22 on C is 26.6 the mean proportion on D.

Ex. 11. Required the content in roods of a piece of walling, 25 feet long, and 10 feet high; set 63, which is the number of feet in a rood on A, to 25 the length on B, and against 10, the height on A is 4 roods nearly on B

Ex. 12. Required the content in roods of a piece of walling, 876 feet long, and 5 feet high; set $272\frac{1}{4}$, which is the area in feet of a rood on A, to 876 the length on B, and against 5, the height on A are 16 roods nearly on B.

CRANE.

Ex. 14. Required the power of a crane handle sufficient to balance a weight of 6000 lbs. hung on a pair of blocks 3 pulleys each, the wheel and roller bearing such proportion as 2 is to 20 in diameter, and the handle and pinion bearing such proportion as 1 is to 10 in radius. Begin first with the weight and pulleys, and say if 6 pulleys give 6000 lbs., 1 pulley or roller will give 1000; or set 6, the number of pulleys on B, to 6000, the number of pounds on A, and against 1 roller on B is 1000 on A, then say if 2, the inches diameter of the roller or axle give 1000, the number of pounds being on it, or the weight over the 6 pulleys, equal to 1000 lbs. then 20 inches, the diameter of the wheel, will be equal to, or require 100 lbs. to balance it.

Operation. Invert your slide and set 2 the diameter of the roller on C to 1000, the number of pounds on A, and against 20, the diameter of the wheel on C is 100 lbs.

to balance the whole on A, then proceed with the handle and pinion, and say if 1 inch, the radius of the handle has 10 lbs. to lift.

Operation. Set 1, the radius of the pinion on C to 100, to the number of pounds to lift on A, and against 10, the radius of the handle on C is 10 lbs. the first power applied on A, the answer sought.

By this rule you may find any proportion of weight in any number of movements of any unequal proportion in any kind of mechanical powers, only observe where more requires more, or less requires less, then your slide must be the right way in, as usual, but when more requires less, and less requires more, then your slide must be inverted.

Ex. 15. Required the velocity in inches per minute of the crane handle, while the weight 6000 lbs. passes through a space of 12.6 per minute.

Operation. Set 6000, the number of pounds on C to 12.6, the number of inches and parts that the weight raises on A, and against 10 lbs. the power applied on C is 75, 600 inches, the velocity per minute on A the answer.

Ex. 16. *Lever.* Suppose a lever with 672 lbs. hung on the short arm 1 foot from the fulcrum or prop, required a weight to balance, hung at 6 feet from the fulcrum or prop, on the long arm, as 1 is to 672, so is 6 to the number sought or answer; observe, it must be worked by inverse proportion.

Operation. Invert your slide, and set 1 on C to 672 on A, and against 6 on C is 112 lbs. the answer on A.

Ex. 17. *Wheel and Axle.* Required a weight hung on the wheel 20 inches diameter to balance 100 lbs. hung on the axle 1 inch diameter.

Operation. Invert your slide, set 1 on C to 100 on A, and against 20 on C is 5, the content on A.

Ex. 18. *Pulleys.* Suppose 1000 lbs. to be hung at a pair of blocks, consisting of 10 pulleys, 5 loose, and 5 fast, or 5 in the upper and 5 in the lower block, what weight should be hung at the last pulley to balance

them? direct proportion, say as 10 pulleys or ropes are to 100 lbs., so is 1 rope or pulley to 10 lbs. the answer sought.

Operation. Set 10 on B to 100 on A, and against 1 on B is 10 the content on A.

Ex. 19. *Inclined Plane.* Required a weight hung on the perpendicular height being 12 inches to balance 75 lbs. hung on the slant height, being 36 inches. Direct proportion, say as 36, slant height is to 75 lbs. so is 12 the perpendicular height to the answer 25 lbs.

Operation. Set 36 on B, to 75 on A, and against 12 on B, is 25 the answer on A.

Ex. 20. *The Wedge.* Required the power of a blow struck on a wedge, whose half thickness 1 inch, and length of one side 25 inches, and resistance 250 lbs.

Operation. 25 on B, to 250 on A, and against 1 on B is 10, the answer on A.

Ex. 21. *The Screw.* Required the resistance or weight lifted in pounds, the circumference of the screw being 20 inches, the power applied being 100 lbs. and the distance between two threads $\frac{3}{4}$ of an inch.

Operation. Invert your slide, and set 100 on C, to 20 on A, and against 75, which is on $\frac{3}{4}$ C, is 2650 the content on A.

Ex. 22. *The Engine Beam.* Suppose the length of the beam from the centre to be 6 feet long, and length of stroke 4 feet long at the beam end, required the length of stroke, the same beam is making at $1\frac{1}{2}$, 3 feet and $4\frac{1}{2}$ feet from the centre, or any other length of stroke within the same dimensions.

Operation. Set 4, the length of stroke on B to 6, the length of the beam from the centre on A, and against $1\frac{1}{2}$, 3 and $4\frac{1}{2}$ feet on A is 1, 2, and 3 feet, the content on B, or any other length that might be wanted within the same dimension.

Ex. 23. Suppose the *piston* of a steam engine to travel 220 feet per minute, and the length of stroke up and down to be 8 feet, what is the number of strokes per minute.

OPERATION. Set 8 on B to 1 on unity on A, and against 220 on B is $27\frac{1}{2}$, the content on A.

Ex. 24. Suppose a *piston* to travel 220 feet per minute, and the number of strokes to be $27\frac{1}{2}$ per minute, what is the length of one stroke up and down.

OPERATION. Set $27\frac{1}{2}$ on A to 220 on B, against 1 on A, being 8 feet, the length of stroke on B.

Ex. 25. Required, the number of feet a piston travels in a minute, length of stroke being 8 feet, and number of strokes being $27\frac{1}{2}$.

OPERATION. Set 1 on A to 8 on B, and against $27\frac{1}{2}$ on A, is 220 on B.

Ex. 26. If a *pendulum* 39.2 inches long, make 60 vibrations per minute, what will one of 12 inches long make.

OPERATION. Invert your slide, and set 39.2 on B to 60 on D, and against 12 on B, is 109, the content on D.

Ex. 27. Required, the number of feet a *stone* will fall in 3 seconds, supposing it to fall 16 feet in the first second.

OPERATION. Set 1 on D to 16 on C, and against 3 on D, is 144 feet, the content on C.

Ex. 28. Required, the *circumference* of a *wheel*, the diameter being 20 inches.

OPERATION. Set 1 on B to 3.14 on A, and against 20 on B, is 63, the content on A.

Ex. 29. Required, the *diameter* of a *wheel*, the circumference being 63 inches.

OPERATION. Set 3.14, which is the circumference of 1 inch on A, to 1, the diameter on B, and against 63, the circumference on A is 20, the diameter on B. By this rule, you find the pitch of all wheels nearly by setting the pitch of the cog on B to 3.14 on A, and against any diameter on B, is the number of cogs on A, or against any number of cogs on A, is the diameter on B.

Ex. 30. Suppose a *drum* upon one shaft 20 inches *diameter*, to make 30 revolutions, which is turned by a first drum; then required the *diameter* of the last drum, that makes 150 revolutions.

Operation. Invert your slide, and set 30, the revolutions of the first drum on A to 20, the diameter of the first drum in C, and against 150, the revolution of the ast drum on A is 4 inches, the diameter of the last drum on C. By this rule, you will find the revolution or diameter of any different speed of any number of drums of an unequal proportion; for, as the revolutions on A are to the diameter on C, so is the diameter to the revolutions on A, or number sought. Observe, the slide must always be inverted in these operations.

Ex. 31. *Tiling* and *Slating*. Required the number of *Squares* contained in a piece of tiling or slating 40 feet long by 15 wide.

Operation. Set 100 the number of feet in a square on A to 40 the length on B, and against 15, the width on A is 6, the content on B.

Ex. 32. Required the number of roods contained in the above dimensions.

Operation. Set 63, the number of feet in a rood on A to 40, the length on B, against 15 on A is $9\frac{1}{2}$ roods the content on B.

Ex. 33. Required the number of tiles sufficient to cover the above dimensions.

Operation. Set 1 on A to $101\frac{1}{2}$, the tiles in a rood on B, and against $9\frac{1}{2}$ the roods on A is 965, the number of tiles required on B.

Ex. 34. *Painters' Work.* Required the number of yards contained in a fence of 70 feet long, by $10\frac{1}{2}$ feet high.

Operation. Set 9, the number of feet in a yard on A to 70 the length on B, and against $10\frac{1}{2}$ on A is $81\frac{3}{4}$ the contents on B.

Ex. 35. *Glaziers' Work.* Required the number of feet contained in a window 60 in. high, and 50 wide.

Operation. Set 144, the number of superficial inches in a foot on A to 60, the length on B, and against 50, the width on A is nearly 21.0 feet, the content on B, or call it 5 feet high, and set 12 on A to 5 on B, and against 50 on A is nearly 21.0 feet, the same as above on B

Ex. 36. *Plasterers' Work.* Required the number of yards contained in a piece of plastering, 42 feet long by $8\frac{1}{2}$ feet high.

Operation. Set 9 on A to 12, the length on B, and against $8\frac{1}{2}$ feet high is $39\frac{3}{4}$ yards nearly on B.

Ex. 37. *Pavers' Work.* Required the number of yards contained in a piece of paving $16\frac{1}{2}$ feet long by $13\frac{3}{4}$ wide.

Operation. Set 9 on A to $16\frac{1}{2}$, the length on B, and against $13\frac{3}{4}$ on A, are 35 yards, the content on B.

Ex. 38. Required the number of bricks sufficient for the above 25 yards, admitting the size of bricks to be 9 by $4\frac{1}{2}$ inches, and a superficial yard to contain 32 bricks.

Operation. Set 1 on A to 32 on B, and against 25 on A are 800 bricks, the content on B.

Ex. 39. *Digging.* Required the number of solid yards contained in a piece of digging 15 feet long, 12 feet wide and 2 feet deep; first find the mean proportion by setting 15 on D to 15 on C, and against 12 on C is 13, 45, the square on D.

Operation. Set 9 the depth on B to 17, the common divisor, on A, and against 13, 45 on D, are 60 yards, the content on C.

Ex. 40. *Timber Measure.* Required the number of cubic feet contained in a piece of timber 22 feet long, and 18 inches $\frac{1}{4}$ girt.

Operation. Set 22, the length on B to 9 the common divisor on A, and against the $\frac{1}{4}$ girt on D are $49\frac{1}{4}$ feet, the content on C.

Ex. 41. Required the product of $2\frac{3}{4}$ inches, multiplied by $2\frac{3}{4}$ inches.

Operation. Set 1 on A to $2\frac{3}{4}$ on B, and against $2\frac{3}{4}$ on A is 7.6, the content on B.

Ex. 42. Required the number of *Horse-power* of a double powered *Patent Steam Engine*, the diameter of the cylinder being 24 inches.

Operation. Set 5 on B to 9 on A, and against 24 on D is 20 the content on C; observe, when the slide stands here, it is a table of diameters and horses'-power, D being a line of diameters, and C being a line of horses'-power.

Ex. 43. Required the *side* of a square in inches equal in area to a right angle triangle, whose base is 126 inches, and perpendicular height 94 inches.

Operation. Set 47, which is half the perpendicular on C to 47 the same on D, and against 126 on C is 76.9 the content on D; observe, taking half the perpendicular is the common rule in all triangles to find the area.

Ex. 44. Required the *side* of a square in feet, equal in area to a common triangle, whose base is 48 feet, and perpendicular height 24 feet.

Operation. Set 12, which is half the perpendicular on C to 12 the same on D, and against 48 on C is 24, the answer on D.

Ex. 45. Required, the *weight* of a *hay-stack*, admitting 1 solid yard, or 27 solid feet, to 1 cwt. 1 qr. 0 lb., and the stack to measure 30 feet long, 12 feet wide, and 10 feet high, up to the hips, or eaves. In this case, it will be necessary to take the length and width about 5 feet high, that is, about the middle, calling this the mean proportion, which will be sufficiently true in cases of this kind.

Operation. The first thing is to find the square of it, which is necessary, in all unequal dimensions, before the question can be stated: this is found by setting 30, the feet long, on 30, the same on D, and against 12, the feet wide on C, are 19, the feet square on D nearly, then set 10, the feet high on B, to this common number or divisor, 136 on A, and against 19, the feet square on D, is 167 cwt. 0 qr. 0 lb., the content on C.

Ex. 46. Required, the content of the top of the stack (that is, that part above the hips or eaves, which contains the roof, &c.,) its length being 30 feet, width being 12, and perpendicular height being 10 feet.

Operation. Set 5, which is half the perpendicular on B, that is, the depth to that common number or divisor 136, as above, and against 19, the square on D, as in example above, is 83 cwt. 1 qr., the content on C. Now, the body of the stack being 167 cwt. 0 qr. 0 lb., which being added to 83 cwt. 1 qr. 0 lb., makes the whole 250 cwt. 1 qr., the answer.

MECHANICS.

THE science of mechanics has been very concisely defined the geometry of motion. It is divided, by Sir Isaac Newton, into the two branches of practical and rational mechanics. Practical mechanics treat of the six mechanical powers, of one or more of which every machine is composed; and rational mechanics comprehends the whole theory of motion, shows how to determine the motions produced by given powers or forces, and, conversely, when the phenomena of the motions are given, how to trace the power of forces from which they arise.

To enter into a full detail of mechanics, would swell this volume beyond its intended limits; and, having dwelt somewhat at large on mechanical exercises, under this head, we shall only add an *Abstract of Mechanics.*

ABSTRACT OF MECHANICS.

OF MATTER.

1. EVERY portion of matter is possessed of the following properties, viz. solidity, extension, divisibility, mobility, inertia, attraction, and repulsion.

2. *Solidity* is that property by which two bodies cannot occupy the same place at the same time. It is sometimes called the impenetrability of matter.

3. The *extension*, like the solidity of matter, is proved by the impossibility of two bodies co-existing in the same place.

4. *Divisibility* is that property by which bodies are capable of being divided into parts removeable from each other.

5. *Mobility* expresses the capacity of matter to be moved from one position or part of space to another.

6. *Inertia* is the term which designates the passiveness of matter, which, if at rest, will for ever remain in that state, until compelled by some cause to move; and, on the contrary, if in motion, that motion will not cease, or abate, or change its direction, unless the body be resisted.

SPACE.

1. SPACE is either absolute or relative.

2. *Absolute space* is merely extension, illimitable, immoveable, and without parts; yet, for the convenience of language, it is usually spoken of as if it had parts. Hence the expression,

3. *Relative space*, which signifies that part of absolute space which is occupied by any body, as compared with any part occupied by another body.

ATTRACTION.

1. ATTRACTION denotes the property which bodies have to approach each other.

2. There are five kinds of attraction, the attraction of *cohesion*, of *gravitation*, of *electricity*, of *magnetism*, and *chemical attraction*.

3. The attraction of cohesion is exerted only at very small distances.

4. The strength of the attraction of cohesion being different in different kinds of matter, is supposed to be the cause of the relative degrees of hardness of different bodies.

5. Capillary attraction is only a particular modification or branch of the attraction of cohesion.

6. The attraction of gravitation is exerted by every particle of matter on every other particle at all distances, but by no means with equal intensity at all distances.

7. Gravitation decreases from the surface of the earth *upwards* as the square of the distance increases; but from the surface of the earth *downwards*, it decreases only in a direct ratio to the distance from the centre.

REPULSION.

1. Repulsion is that property in bodies, whereby, if they are placed just beyond the sphere of each other's attraction of cohesion, they mutually fly from each other.

2. Oil refuses to mix with water, from the repulsion between the particles of the two substances; and from the same cause, a needle gently laid upon water will swim.

MOTION.

1. *Absolute motion* is the actual motion that bodies have, considered independently of each other, and only with regard to the parts of space.

2. *Relative motion* is the degree and direction of the motion of one body, when compared with that of another.

3. *Accelerated motion* is when the velocity continually increases.

4. *Retarded motion* is when the velocity continually decreases; and the motion is said to be *uniformly retarded*, when it decreases equally in equal times.

5. The velocity of uniform motion is estimated by the time employed in moving over a certain space; or, which amounts to the same thing, by the space moved over in a certain time.

6. To ascertain the velocity, divide the space run over by the time.

7. To ascertain the space run over, multiply the velocity by the time.

8. In accelerated motion, the space run over is as the *square* of the time, instead of being directly as the time, as in uniform motion.

9. A body acted upon by only one force, will always move in a straight line.

10. Bodies acted upon by two single impulses, whether equal or unequal, will also describe a right line.

11. But when a body is acted upon by one uniform force, or single impulse, and another accelerated or retarded force, the two forces will cause it to describe a *curve*.

12. The curve described by a body projected from the earth, and drawn down by the action of gravity, would in an unresisting medium, be that of a parabola; bu from the resistance of the air, which, when the velocity is very great, will often amount to one hundred times the weight of the projectile, the curve really described approaches more nearly to that of a hyperbola.

13. The *momentum* of a body is the force with which it moves, and is in proportion to the weight, or quantity of matter, multiplied into its velocity.

14. The actions of bodies on each other are always equal, and exert in opposite directions; so that any body acting upon another, loses as much force as it commu nicates.

CENTRAL FORCES.

1. THE central forces are the *centrifugal* and the *centripetal* forces.

2. The centrifugal force is the tendency which bodies that revolve round a centre, have to fly from it in a tangent to the curve they move in, as a stone from a sling.

The centripetal force is that which prevents a body from flying off, by impelling it towards the centre, as the attraction of gravitation.

CENTRE OF GRAVITY.

1. THE centre of gravity is that point in a body about which all its parts exactly balance each other in every position.

2. A vertical line passing through the centre of gravity of a body, is called the *line of direction.*

3. When the line of direction falls within the base of a body, that body cannot descend; but if it falls without the base, the body will fall.

THE LEVER.

1. THERE are three kinds of levers, the difference between which is constituted by the difference in the

situation of the fulcrum, and the power with respect to each other. In the *first* kind of lever, the fulcrum is placed between the power and the weight. In the *second* kind of lever, the fulcrum is at one end, the power at the other, and the weight between them. In the *third* kind of lever, the power is applied between the fulcrum and the weight.

2. In all these levers, the power is to the weight, as the distance of the weight from the fulcrum is to that of the power from the fulcrum.

3. A *bent* or hammer lever, differs only in the form from a lever of the first kind.

4. *Scissors*, *pincers*, *snuffers*, and the common *iron-screw*, are all levers of the first kind.

5. The *strutera* or Roman *steel-yard*, is a lever of the first kind, with a moveable weight.

6. A *balance* is also a lever of the first kind with equal arms; a perfect balance should combine the following requisites. 1. The arms of the beam should be exactly equal, both as to weight and length, and should at the same time be as long as possible, relatively to their thickness. 2. The points from which the scales are suspended, should be in a right line, passing through the centre of gravity of the beam. 3. The fulcrum ought to be a little higher than the centre of gravity. 4. The axis of motion should be formed with an edge like a knife, and, with the rings and other bearing parts, should be very hard and smooth. 5. The pivots, which form the axis of motion, should be in a straight line, and at right angles to the beam.

7. The best balauces are not calculated to determine weights with certainty to more than five places of figures.

8. The oars and rudders of vessels are levers of the second order; a pair of bellows, nut-crackers, &c. are composed of two levers of the same kind.

9. The third kind of lever is used as little as possible, on account of the disadvantage to the moving power, the intensity of which must always exceed the resistance

yet in some cases this disadvantage is over-balanced by the quickness of its operations, and the small compass in which it is exerted; hence its fitness for the bones of the arm, and the limbs of animals generally.

10. In compound levers, the power is to the weight, in a ratio compounded of the several ratios which those powers that can sustain the weight by the half of each lever, when used singly and apart from the rest, have to the weight.

THE PULLEY.

1. PULLEYS are of two kinds, *fixed* and *moveable*.

2. The fixed pulley only turns upon its axis, and affords no mechanical advantage; therefore, when the power and the weight are equal, they balance each other. It is used for the convenience of changing the direction of a motion.

3. The *moveable* pulley not only turns upon its axis, but rises and falls with the weight.

4. Every moveable pulley may be considered as hanging by two ropes equally stretched, and which, consequently, being equal portions of the weight, therefore each pulley of this sort doubles the power.

5. A pulley of one spiral groove upon a truncated cone as the fusee of a watch, is calculated to maintain a constant equilibrium or relation between two powers, the relative forces of which are continually changing.

WHEEL AND AXLE.

1. THE power must be to the weight, in order to produce an equilibrium, as the *circumference* of the wheel is to the *circumference* of the axle.

2. As the diameters of different circles bear the same proportion to each other that their respective circumferences do, the power is also to the weight as the *diameter* of the wheel to the *diameter* of the axle.

3. If one wheel move another of equal circumference no power will be gained, as they will both move equally fast.

4. But if one wheel move another of different diameter, whether larger or smaller, the velocities with which they move will be inversely as their diameters, circumferences, or number of teeth.

5. The wheel and axle may be considered as a perpetual lever, from the constant renewal of the points of suspension and resistance. The fulcrum is the centre of the axis, the longer arm is the radius of the wheel, and the shorter arm the radius of the axis.

6. The crane, and many other machines, of the first consequence, are composed principally of the wheel and axle.

THE INCLINED PLANE.

1. The power and the weight balance each other, when the former is to the latter as the height of the plane to its length.

2. In estimating the draught of a wagon, or other vehicle, up-hill, the draught on the level must be added; so that, if the hill rises one foot in four, one fourth part of the weight must be added to the draught on level ground.

THE WEDGE.

1. When the resistance acts perpendicularly to the sides, that is, when the wedge does not cleave at any distance, there is an equilibrium between the resistance and the power, when the latter is to the former as half the thickness of the back of the wedge is to the length of one of its sides.

2. When the resistance on each side acts parallel to the back, that is, when the wedge cleaves at some distance, the power is to the resistance as the whole length of the back to double its perpendicular height.

3. The thinner the wedge, the greater its power.

4. The further a wedge is driven into any material, the greater also is its power, the sides of the cleft affording it the advantage of operating upon two levers.

5. Axes, spades, chisels, knives, and all instruments

which begin with edges or points, and grow gradually thicker, act on the principle of the wedge.

THE SCREW.

1. The screw is an inclined plane encompassing the cylinder.

2. It is generally used with a lever; and the power is to the weight, as the distance from one thread or spiral to another is to the circumference of the circle described by the power.

3. The friction of the screw is very great, a circumstance that occasions this machine to sustain a weight or press upon a body, after the power by which it was impelled is removed.

4. A screw cut on an axle to serve as a pinion, is called an *endless screw.*

5. The endless screw is very useful, either in converting a very rapid motion into a slow one, or *vice versa*, as for each of its revolutions the wheel moves but one-tenth.

COMPOUND MACHINES.

1. In all machines, simple as well as compound, what is gained in power is lost in time; but the loss of time is compensated by convenience.

2. The mechanical power of an engine may be known by measuring the space described in the same time by the power and the resistance or weight; or by multiplying into each other the several proportions subsisting between the power and the weight, in every simple mechanical power of which it is composed.

3. The power of a machine is not altered by varying the size of the wheels, provided the proportion produced by the multiplication of the power of the several parts remains the same.

4. In constructing machines, simplicity of parts and uniformity of motion should be particularly studied.

5. The teeth of wheels should always be made as numerous as possible; and when great strength is required, it should be obtained by increasing the width or thickness of the wheel.

6. The use of the crank is one of the best modes of converting a reciprocating into a rotatory motion, and *vice versa.*

FLY-WHEELS.

1. A fly-wheel is a *reservoir* of power, and is employed to *equalize* the motion of a machine.

2. This equalization of the motion is the only source of the advantage of a fly, which can impart no power it has not received.

3. When a fly is used merely as a regulator, it should be near the first mover; if intended to accumulate force in the working point, it should not be separated far from that point.

FRICTION.

1. Friction is occasioned by the roughness and cohesion of bodies.

2. It is in general equal to between one-half and one-fourth of the weight or force with which bodies are pressed together.

3. It is increased in a small degree by an increase of the surfaces in contact.

4. It is increased to an extraordinary degree, by prolonging the time of contact.

5. Two metals of the same kind have more friction than two different metals.

6. Steel and brass are the two metals which have the least friction upon each other.

7. The general rule for lessening friction consists in substituting the rolling for the sliding motion.

MEN AND HORSES, CONSIDERED AS FIRST MOVERS.

1. In turning a wrench, a man exerts his strength in different proportions at different parts of the circle. The force is, when he pulls the handle up from the height of his knee; and the least when he thrusts from him horizontally.

2. When two handles are used to an axle, one at each extremity, they should be fixed at right angles to each other.

3. The art of carrying large burdens, consists in keeping the column of the body as directly under the weight and as upright as possible.

4. The horse exerts his force to the greatest advantage in drawing or carrying up a hill.

5. The force with which a horse works, is compounded of his weight and muscular strength.

6. The walk of a horse working in a mill should never be less than forty feet in diameter.

7. A horse exerts most strength when drawing upon a plane.

MILL-WORK.

1. WATER-WHEELS are of three kinds; viz. undershot-wheels, breast-wheels, and overshot-wheels. The powers necessary to produce the same effect on each of these must be to each as the numbers 2.4, 1.75, and 1.

2. The *undershot-wheel* is used only when a fall-water cannot be obtained.

3. A water-wheel twice as broad as another has more than double the force.

4. An axis, furnished with a very oblique spiral, and placed in the direction of a stream, may be rendered a powerful first-mover, adapted to a deep and slow current.

5. A mill-stone should make 120 revolutions in a minute.

6. *Bevelled-wheels* are much used for changing the direction of motion in wheel work.

7. Hooke's *universal joint* is sometimes used with advantage for the same purpose.

8. The teeth of wheels should never, if it can be avoided, act upon each other before they arrive at the line joining the centres.

9. To ensure a uniformity of pressure and velocity in the action of one wheel upon another, the teeth should be formed into epicycloides, or into involutes, of the cir-

cumferences of the respective wheels; or if the teeth of one wheel be either circular or triangular, the teeth of the same wheel should have a figure compounded of an epicycloid, and that of the figure of the first wheel.

10. The object of thus forming the teeth is, that they may not *slide*, but *roll* upon each other; by which means, the friction is almost annihilated.

11. It is a great improvement in machinery, where trundles are employed with cylindrical staves, to make these staves moveable on their axis.

12. A heavy mill-stone requires very little more power than a light one; but it performs much more work, and more effectually equalizes the motion, like a heavy fly.

13. The corn as it is ground, is thrown out between the mill-stones, by the centrifugal force it has acquired.

14. The manual labour of putting the ground corn into sacks, in order to raise it to the top of a mill-house, may be obviated by the use of a chain of buckets wrought by machinery.

WHEEL CARRIAGES.

1. A HORSE draws with the greatest advantage, when the line of traction or draught is inclined upwards, so as to make an angle of about 15 degrees with the horizontal plane.

2. By this inclination, the line of traction is set at right angles to the shape of the horses' shoulders, all parts of which are, therefore, equally pressed by the collar.

3. Single horses are preferable to teams, because in a team, all but the shaft horse draw horizontally, and consequently to disadvantage.

4. A horse, when part of the weight presses on his back, will draw a weight to which he would otherwise be incompetent.

5. The fore-wheels of carriages are less than the hind-wheels, for the convenience of turning in a smaller compass.

6. In ascending, high wheels facilitate the draught, in

proportion to the squares of their diameters; but in descending, they press in the same proportion.

7. In descending, the body of a cart may be advantageously thrown backwards, so that the bottom of it will be horizontal, while the shafts incline downwards.

8. In loading four-wheeled carriages, the greatest weight should be laid upon the large wheels.

9. Dished wheels are better calculated than any other to sustain the jolts and unavoidable inequalities of pressure arising from the roughness of roads.

10. The extremities of the axles should be in the same horizontal plane, and the wheels should be placed on them at right angles.

11. Broad cylindrical wheels smooth and harden a road, while narrow ones cut it into furrows, and conical ones grind the hardest stones to powder.

CLOCK-WORK.

1. To ascertain the number of revolutions which a pinion makes, for one of the wheels working in it, divide the number of its leaves by the number of teeth of the wheel, and the answer is obtained.

2. By increasing the number of teeth in the wheels; by diminishing the number of leaves in the pinions; by increasing the length of the cord that suspends the weight; and lastly, by adding to the number of wheels and pinions, a clock may be made to go any length of time, as a month, or a year, without winding up.

3. The inconvenience of taking up more room, but principally the increase of friction which would be introduced, are the causes of its being inexpedient to make a clock go beyond eight days.

4. Clocks intended to keep exact time, are contrived to go whilst winding up.

5. Clocks which have pendulums vibrating half seconds, are frequently moved by a spring instead of a weight.

6. A spring is strongest when it is first wound up, and gradually decreases in strength till the movement stops

it is therefore contrived to draw the chain over a conical barrel, so that the lever at which it pulls is lengthened as it grows weaker, by which means its effects are equalized.

7. The plates of clock-makers' engines may be quickly divided into odd numbers, by subtracting from the odd number so much as will leave an even number of easy subdivision; then calculating the number of degrees contained in the parts subtracted, and setting them off on the circumference of the circle from a sector.

8. The geometrical radius of wheels, when the teeth are epicycloidal, is less than the acting diameter, by about $\frac{2}{7}$ths of the breadth of a teeth or measure.

9. The relative size of a pinion must be less for a small wheel than for a large one, and also smaller when driven than when it is the driver.

PENDULUMS.

1. All vibrations of the same pendulum, whether great or small, if cycloidal, are performed in equal times.

2. The longer a pendulum, the slower are its vibrations.

3. A pendulum to vibrate seconds, must be shorter at the equator than at the poles.

4. Heat lengthens and cold shortens pendulums.

5. The quicksilver pendulum, the gridiron pendulum, and many others, have been contrived to obviate these effects of the change of temperature.

6. The vibrations of pendulums are affected by differences in the density of the medium in which they are performed.

7. The merit of the only contrivance to remedy this defect is due to Rittenhouse. It consists in the use of two pendulums, one of which is very light, and placed in an inverted position, extending above the point of suspension of the other.

8. This compound pendulum may be made to vibrate quicker in so dense a medium as water than in the open air

A

GENERAL AND MOST USEFUL SELECTION

OF

RECEIPTS:

WHICH WILL PROVE OF THE GREATEST UTILITY

TO

THE ARTIST, THE MECHANIC,

THE FARMER, AND THE LABOURING MAN.

EMBRACING

THE WHOLE COURSE OF THE ARTS,

Selecting and reducing such parts as are often wanted, when the employment of the professors of such business would be too expensive and embarrassing. The aid of which will enable also the experimenter impelled by genius to perform and invent with greater ease and success, in some cases; while in others obstacles will be removed that otherwise would be insurmountable.

MISCELLANEOUS RECEIPTS.

Method for making Black Writing-Ink.

In six quarts of water, boil four ounces of logwood in chips, cut very thin across the grain. The boiling may be continued for nearly an hour, adding, from time to time, a little boiling water, to compensate the waste by evaporation. Strain the liquor while hot, suffer it to cool, and make up the quantity equal to five quarts, by the further addition of cold water. To this decoction, put

1 lb. avoirdupois of blue galls, coarsely bruised; or
20 oz. of the best galls, in sorts.
4 oz. of sulphate of iron, calcined to whiteness.
½ oz. of acetate of copper, previously mixed with the decoction till it forms a smooth paste.
3 oz. of coarse sugar, and
6 oz. of gum-Senegal or Arabic.

These several ingredients may be introduced one after another, contrary to the advice of some, who recommend the gum, &c. to be added when the ink is nearly made. The composition produces the ink usually called Japan Ink, from the high gloss which it exhibits when written with; and a small phial of it has been sold for 12 cents.

The above ink, though possessing the full proportion of every ingredient known to contribute to the perfection of ink, will not cost more, to those who prepare it for themselves, than the commonest ink which can be bought by retail. The receipt was given to the public by Desormeaux. It answers for copying letters, by transferring from them an impression to a damp sheet of thin, unsized paper, passing through a small rolling-press.

When gum is very dear, or when no very high gloss

is required, four ounces will be sufficient, with one ounce and a-half of sugar.

By using only 12 oz. of galls to 4 oz. of sulphate of iron, uncalcined, omitting the logwood, and acetate of copper, and the sugar, and using only 3 oz. of gum, a good and cheap common ink will be obtained.

Lamp-black has been added to ink, to prevent its colour from being destroyed by the action of the oxy-muriatic acid. It should be burnt in a closed crucible, to render it less oily. It causes the ink to write much less freely, although it may be useful for particular occasions.

Red-Ink for Writing.

Boil over a slow fire, 4 oz. of Brazil-wood, in small raspings or chips, in a quart of water, till a third part of the water is evaporated. Add during the boiling, two drams of alum in powder. When the ink is cold, steam it through a fine cloth. Vinegar or stale urine is often used instead of water. In case of using water, I presume a very small quantity of sal-ammoniac would improve this ink.

Blue-Ink.

Take Sulphate of Indigo, dilute it with water till it produces the colour required. It is with sulphate very largely diluted, that the faint blue lines of ledgers and other account books are ruled. If the ink were used strong, it would be necessary to add chalk to it, to neutralize the acid. The sulphate of indigo may be had of the woollen dyers.

Fire and Water-proof Cement.

To half a pint of milk, put an equal quantity of vinegar, in order to curdle it; then separate the curd from the whey, and mix the whey with four or five eggs, beating the whole well together. When it is well mixed, add a little quicklime through a sieve, until it has acquired the consistence of a thick paste. With this

cement, broken vessels and cracks of all kinds may be mended. It dries quickly, and resists the action of water as well as of a considerable degree of fire.

A Cement for stopping the Fissures of Iron Vessels.

Take two ounces of muriate of ammonia, one ounce of flowers of sulphur, and sixteen ounces of cast-iron filings or turnings; mix them well in a mortar, and keep the powder dry. When the cement is wanted, take one part of this and twenty parts of clean iron filings or borings, grind them together in a mortar, mix them with water to a proper consistence, and apply them between the joints.

This answers for flanges of pipes, &c. about steam engines.

Lutes.

Lutes are compositions which are employed to defend glass and other vessels from the action of fire, or to fill up the vacancies which occur, when separate tubes, for the necks of different vessels, are inserted into each other during the process of distillation. Those lutes which are exposed to the action of fire, are usually called *fire lutes.*

For a very excellent fire-lute, which will enable glass vessels to sustain an incredible degree of heat, take fragments of porcelain, pulverize and sift them well, and add an equal quantity of fine clay, previously softened with as much of a saturated solution of muriate of soda, as is requisite to give the whole a proper consistence. Apply a thin and uniform coat of this composition to the glass vessels, and allow it to dry slowly before they are put into the fire.

Equal parts of coarse and refractory clay mixed with a little hair, form a good lute.

Fat earth, beaten up with fresh horse-dung, Chaptal recommends as an excellent fire-lute, which he generally used, and the adhesion of which was such, that after the retort had cracked, the distillation could be carried on and regularly finished.

Lutes for the joining of such vessels as retorts and receivers, are varied according to the nature of the vapours which will act against them, in order not to employ a more expensive and troublesome composition than the case requires. For resisting watery vapours, slips of wet bladder, or slips of wet paper or linen, covered with stiff flour paste, may be bound over the juncture.

A closer and neater lute for more penetrating vapours, is composed of whites of eggs made into a smooth paste with quick-lime, and applied upon strips of linen. The quick-lime should be previously slacked in the air, and reduced to a fine powder. The cement should be applied the moment it is made; it soon dries, becomes very firm; and is in chemical experiments one of the most useful cements known.

Where saline, acrid vapours are to be resisted, a lute should be composed of boiled linseed oil intimately mixed with clay, which has been previously dried, finely powdered, and sifted. This is called fat lute. It is applied to the junctures, as the undermost layers, and is secured in its place by the white of egg-lute last mentioned, which is tied on with pack-thread.

Blacking, to make.

Put 1 gallon of vinegar into a stone jug, add 1 lb. of ivory-black, well pulverized, ½ a lb. of loaf sugar, ½ an oz. of oil of vitriol, and 1 oz. of sweet oil; incorporate the whole by stirring.

This is a blacking of very great repute in different countries, and on which great praise has been very deservedly bestowed. It has decidedly been ascertained, from experience, to be less injurious to the leather, than most public blackings; and it certainly produces a fine jet polish, which is rarely equalled, and never yet surpassed.

VARNISHES.

To dissolve Copal in Alcohol.

Copal, which is called gum copal, but which is not, strictly, either a gum or a resin, is the hardest and least changeable of all substances adapted to form varnishes, by their dissolution in spirit, or essential, or fat oils. It, therefore, forms the most valuable varnishes; though we shall give several receipts where it is not employed, which form cheaper varnishes, sufficiently good for many purposes, adding only the general rule, that no varnish must be expected to be harder than the substance from which it is made.

To dissolve copal in alcohol, dissolve half an ounce of camphor in a pint of alcohol; put it into a circulating glass, and add 4 oz. of copal in small pieces; set it in a sand-heat, so regulated that the bubbles may be counted as they rise from the bottom, and continue the same heat till the solution is completed.

The process above-mentioned will dissolve more copal than the menstruum will retain when cold. The most economical method will therefore be, to set the vessel which contains the solution by for a few days, and, when it is perfectly settled, pour off the clear varnish, and leave the residue for future operation.

The solution of copal thus obtained is very bright. It is an excellent varnish for pictures, and would, doubtless, be an improvement in japanning, where the stoves used for drying the varnished articles would drive off the camphor, and leave the copal clear and colourless in the work.

To dissolve Copal in Spirits of Turpentine.

Reduce 2 oz. of copal to small pieces, and put them into a proper vessel. Mix a pint of the best spirits of turpentine with one eighth of spirits of sal ammoniac; shake them well together, put them to the copal, cork

the glass, and tie it over with a string or wire, making a small hole through the cork. Set the glass in a sand-heat so regulated as to make the contents boil as quickly as possible, but so gently that the bubbles may be counted as they rise from the bottom. The same heat must be kept up exactly till the solution is complete.

It requires the most accurate attention to succeed in this operation. After the spirits are mixed, they should be put to the copal, and the necessary degree of heat be given as soon as possible, and maintained with the utmost regularity. If the heat abates, or the spirits boil quicker than is directed, the solution will immediately stop, and it will afterwards be in vain to proceed with the same materials; but if properly managed the spirit of sal ammoniac will be seen gradually to descend from the mixture, and attack the copal, which swells and dissolves, excepting a very small quantity which remains undissolved.

It is of much consequence that the vessel should not be opened till some time after it has been perfectly cold; for if it contain the least warmth when opened, the whole contents will be blown out of the vessel.

Whatever quantity is to be dissolved, should be put into a glass vessel capable at least of containing four times as much, and it should be high in proportion to the width.

This varnish is of a deep rich colour, when viewed in the bottle, but seems to give no colour to the pictures upon which it is laid. If it be left in the damp, it remains racky, as it is called, a long time; but if kept in a warm room, or placed in the sun, it dries as well as any other turpentine varnish, and when dry it appears to be as durable as any other solution of copal.

Copal may also be dissolved in spirits of turpentine by the assistance of camphor.

Turpentine varnishes dry more slowly than those made with alcohol, and are less hard; but they are not so liable to crack.

To dissolve Copal in fixed-Oil.

Melt, in a perfectly clean vessel, by a very slow heat, one pound of clear copal; to this, add from one to two quarts of drying linseed oil. When these ingredients are thoroughly mixed, remove the vessel from the fire, and keep constantly stirring it, till nearly cold; then add a pound of spirits of turpentine. Strain the varnish through a piece of cloth, and keep it for use. The older it is, the more drying it becomes.

This varnish is very proper for wood-work, house and carriage painting.

Seed-lac Varnish.

Take three ounces of seed-lac, and put it, with a pint of spirits of wine, into a bottle, of which it will not fill more than two-thirds. Shake the mixture well together, and place it in a gentle heat, till the seed-lac appears to be dissolved: the solution will be hastened by shaking the bottle occasionally. After it has stood some time, pour off the clear part, and keep it for use in a well-stopped bottle. The seed-lac should be purified before it is used, by washing it in cold water, and it should be in coarse powder, when added to the spirit.

This varnish is next to that of copal in hardness, and has a reddish-yellow colour: it is, therefore, only to be used where a tinge of that kind is not injurious.

Shell-lac Varnish.

Take five oz. of the best shell-lac, reduce it to a gross powder, and put it into a bottle in a gentle heat, or a warm, close apartment, where it must continue two or three days, but should be frequently well shaken. The lac will then be dissolved, and the solution should then be filtered through a flannel bag; and, when the portion that will pass through freely is come off, it should be kept for use in well-stopped bottles.

The portion which can only be made to pass through the bag by pressure, may be reserved for coarse purposes.

Shell-lac varnish is rather softer than seed-lac varnish, but it is the best of varnishes for mixing with colours to paint with, instead of oil, from its working and spreading better in the pencil.

Varnish for Toys, Silvered Clock-faces, and Furniture, not exposed to hardship.

Dissolve two ounces of gum-mastic, and eight ounces of gum-sandrach, in a quart of alcohol; then add four ounces of Venice turpentine. The addition of a little of the whitest part of gum-benjamin will render the varnish less liable to crack.

Amber Varnish.

Amber forms a very excellent varnish: its solution may be effected by boiling it in drying linseed oil.

Oil-varnishes, which have become thick by keeping, are made thinner with spirits of turpentine.

A Varnish for Copper-plate Prints.

Prepare water by dissolving in it some isinglass; lay on, with a soft brush, a coat of this. Let dry. Put on another, if necessary. Let dry. Then lay on another, of the following varnish.—True French spirit of wine, half a pound; gum-elemi, two drachms, and sandarach, three.

A curious and easy Varnish to engrave with aquafortis.

Lay on a copper-plate as smooth and equal a coat as possible, of linseed oil. Set the plate on a gentle heat, that the oil may congeal, and dry itself in. When you find it has acquired the consistence of a varnish, then you may draw with a steel point, in order to etch your copper, and put on the aquafortis afterwards.

A Varnish to gild with, without Gold.

Take half a pint of spirits of wine, in which you dissolve one drachm of saffron, and half a drachm of dra

gon's blood, both previously well pulverized together. Add this to a certain quantity of shell-lac varnish, and set it on the fire with two drachms of soccotrine aloes.

Japanning.

JAPANNING is the art of varnishing in colours, and is frequently combined with painting.

The substances proper for japanning, are wood, metal, with all others which retain a determinate form, and are capable of sustaining the operation of drying the varnish. Paper and leather, therefore, when wrought into forms in which they remain stretched, stiff, and inflexible are very common subjects for japanning.

The article to be japanned is first rendered smooth and perfectly clean, it is then brushed over with two or three coats of seed-lac varnish, (see under the head of *varnishes*) except that the coarsest varnish will answer the purpose. The varnish thus laid on is called the *priming*. The next operation is to varnish the article again with the best varnish previously mixed with a pigment of the tint desired. This is called the *grounding;* if the subject is to exhibit any painting, the objects are painted upon it, in colours mixed up with varnish, and used in the same manner as for oil-painting. The whole is then covered with additional coats of transparent varnish, and all that remains to be done, is to dry and polish it.

Japanning should always be executed in warm apartments, as cold and moisture are alike injurious; and all the articles should be warmed before any varnish is applied to them. One coat of varnish, also, must be dry before another is laid on. Ovens are employed to hasten the perfect drying of the work.

All the coloured pigments employed in oil or water, answer perfectly well in varnish, combined with which vehicle, many of those which fly in oil are perfectly unchangeable. The manner in which the colours are mixed with the varnish is extremely simple and easy; they are first reduced, by the usual means of washing

and levigation, to the finest state possible; and the varnish being contained in a bottle, they are added to it, till the requisite body of colour is obtained, the mixture being rendered complete by stirring or shaking the bottle. When a single colour is intended, the varnish employed is of no consequence, if it be hard enough for the work, and not possessed of any colour inconsistent with the tint required; but for painting with, shell-lac varnish is the best, and easiest to work: it is, therefore, employed in all cases where its colour permits, and for the lightest colours, mastic varnish is employed, unless the fineness of the work admits the use of copal dissolved in spirits of wine.

To spare varnish, the priming may be composed of size mixed with whiting, to give it a body, as some substances require much varnish to saturate them; but work primed with size is never durable; it is liable to crack and fly off with the least violence, which never happens to work into which the varnish can sink. Varnish cannot sink into metals, and this is the reason that japanned metal, for example a japanned tin-plate tray, is of less value than a paper one. The battering which this piece of furniture sustains in its use, soon separates the japan from it in flakes, or scales; which never happens to the paper, because the japan forms a part of its substance.

It may be observed, that only wood, paper, leather, and similar substances, require priming; metals require none, because they admit no varnish into them, and therefore the ground is applied to them immediately.

The priming and grounds are all laid on with brushes made of bristles: the painting will of course often require a camels'-hair pencil.

Of Japan Grounds.

Red.—Vermilion makes a fine scarlet, but its appearance in japanned work is much improved by glazing it with a thin coat of lake, or even rose pink.

Indian lake, when good, is perfectly soluble in spirits

of wine, and produces a fine crimson, but is not often to be obtained.

Yellow.—King's yellow, turbith mineral, and Dutch pink, all form very bright yellows, and the latter is very cheap. Seed-lac varnish assimilates with yellow very well; and when they are required very bright, an improvement may be effected by infusing turmeric in the varnish which covers the ground.

Green.—Distilled verdigris laid on a ground of leaf gold, produces the brightest of all greens; other greens may be formed by mixing king's yellow and bright prussian blue, or turbith mineral and prussian blue, or Dutch pink and verdigris.

Blue.—Prussian blue, or verditer glazed with Prussian blue or smalt.

White.—White grounds are obtained with greater difficulty than any other. One of the best is prepared by grinding up flock-white, or zinc-white, with one sixth of its weight of starch, and drying it; it is then tempered, like the other colours, using the mastic varnish for common uses; and that of the best copal for the finest. Particular care should be taken, that the copal for this use be made of the clearest and whitest pieces. Seed-lac may be used as the uppermost coat, where a very delicate white is not required, taking care to use such as is least coloured.

Black.—Ivory-black or lamp-black; but if the lamp-black be used, it should be previously calcined in a closed crucible.

Black grounds may be formed on metal, by drying linseed oil only, when mixed with a little lamp-black.

The work is then exposed in a stove to a heat which will render the oil black. The heat should be low at first, and increased very gradually, or it will blister. This kind of japan requires no polishing. It is extensively used for defending articles of iron-mongery from rust.

Tortoise-shell ground for metal.—Cover the plates intended to represent the transparent parts of the tortoise-shell, with a thin coat of vermilion in seed-lac

varnish. Then brush over the whole with a varnish composed of linseed oil boiled with umber until it is almost a black. The varnish may be thinned with oil of turpentine before it is used. When the work is done, it may be set in an oven, with the same precautions as the black varnish last named.

Polishing of varnished and japanned work.

Pictures and other subjects, to which only a single coat or two of thin varnish is given, are generally left to the polish which the varnish naturally possesses, or brightened only by rubbing it with a woollen cloth, after it is dry; but wherever several coats of varnish or japan are laid on, a glossy surface is produced by the means used to polish metals; the surface having been suffered to become completely dry and hard.

When the coat of varnish is very thick, the surface may be rubbed with pumice-stone and oil, until it becomes uniformly smooth; the pumice should first be reduced to a smooth flat face by rubbing it on a piece of freestone, or something to answer the same purpose. The japanned or varnished surface may afterwards be rubbed with pumice reduced to an impalpable powder. The finishing may be given by oil and woollen rag only.

When the varnish is thinner, and of a more delicate nature, it may be rubbed with tripoli or rotten-stone, in fine powder, finishing with oil as before. When the ground is white, putty or spanish white, finely washed, may be used instead of rotten-stone, of which the colour might have some tendency to injure the ground.

Preparation of Drying Linseed Oil.

Frequent reference has been made to the use of drying linseed oil: it may be necessary to observe, that to render linseed oil drying consists simply in mixing it with litharge, or any oxide of lead, boiling it slowly for some time, and straining it from the sediments after it has stood to clarify. The oil thus treated, beomes thicker as it imbibes oxygen from the oxide, and acquires the property of drying much

sooner than before. An ounce of litharge may be used in every pound of oil.

To render Boots and Shoes water-proof.

Take one pint of drying oil, two ounces of yellow wax, two ounces spirits of turpentine, and half an ounce of Burgundy pitch, melt them over a slow fire, and thoroughly incorporate them by stirring. Lay this mixture on new shoes and boots, either in the sun or at some distance from the fire, with a sponge or brush, and repeat the operation as often as they become dry, until they are fully saturated. The shoes and boots thus prepared, ought not to be worn until the leather has become perfectly dry and elastic. They will then be found impervious to moisture, and their durability will be increased.

Method of preparing a cheap Substitute for Oil Paint.

It often happens that people do not choose, or cannot employ oil-painting in the country, either because it does not dry soon enough, and has a disagreeable smell, or because it is too costly. Ludicke employed with the greatest success the following composition for painting ceilings, gates, doors, and even furniture.

Take fresh curds, and bruise the lumps on a grinding-stone, or in an earthen pan or mortar, with a spatula. After this operation, put them in a pot with an equal quantity of lime, well quenched, and become thick enough to be kneaded: stir the mixture well, without adding water, and a whitish semi-fluid mass will be obtained, which may be applied with great facility like paint, and which dries very rapidly. It must be employed the day it is prepared, as it will become too thick the following day. Ochre, armenian bole, and all colours which hold with lime, may be mixed with it, according to the colour desired; but care must be taken, that the addition of colour made to the first mixture of curds and lime, contain very little water, or it will diminish the durability of the painting.

When two coats of this painting have been laid on it

may be polished with a piece of woollen cloth, or other proper substance, and it will become as bright as varnish. This kind of painting, besides its cheapness, possesses the advantage of admitting the coats to be laid on and polished in one day; as it dries speedily, and has no smell.

A Cement which answers for cast iron Pipes, or wooden Logs.

Take 12 or 14 lbs. of fine cast iron borings, put them in a vessel with as much water as will just wet them through; mix with them ½ lb. of pounded sal ammoniac, and 2 oz. of flour of sulphur; mix all well together, and let stand three or four hours: they are then ready for use. If not used immediately, cover them with water till used.

Bronzing.

Bronze of a good quality acquires, by oxidation, a fine green tint, called *patina antiqua*. Corinthian brass receives, in this way, a beautiful clear green colour. This appearance is imitated by an artificial process, called *bronzing*. A solution of sal ammoniac and salt of sorel in vinegar is used for bronzing metals. Any number of layers may be applied, and the shade becomes deeper in proportion to the number applied. For bronzing sculptures of wood, plaster-figures, &c., a composition of yellow ochre, Prussian blue, and lamp-black, dissolved in glue-water, is employed.

Caoutchouc, or India Rubber, how dissolved, uses, &c.

Caoutchouc is brought principally from South America: the juice, obtained from incisions, is applied in successive layers, over a mould of clay, and dried by exposure to the sun, and to the smoke from burning fuel. When perfectly dry, the mould is broken, leaving the caoutchouc in the form of a hollow ball. It is insoluble in alcohol and in water. Sulphuric ether, when purified by washing in water, dissolves it; and, by evaporation, the caoutchouc may be discovered unchanged.

Oil of turpentine softens it, and forms with it a sort of paste that may be spread as a varnish; but it is very long in drying. The fluid now commonly used to dissolve it is the purified naphtha from coal tar, which is, at the same time, a cheap and effectual solvent, and which does not change its properties. This solution is employed to give a thin covering of caoutchouc to cloth, which is thus rendered impervious to moisture. Caoutchouc is also readily soluble in cajeput oil.

Caoutchouc, from its softness, elasticity, and impenetrability to water, is applied to the formation of catheters, bougies, and tubes for conveying gases. These are formed by twisting a slip of it round a rod, and causing the edges to adhere by pressure, when softened by maceration in warm water. It is also used very extensively in this country for over-shoes; and its solution in oils forms a flexible varnish.

The following Composition will render Boots or Shoes impervious to Water.

Take neat's-foot oil, and dissolve in it caoutchouc, a sufficient quantity to form a kind of varnish; rub this on the boots. This is sufficient.

N. B. The oil must be placed where it is warm, the caoutchouc put into it in parings. It will take several days to dissolve it.

An excellent Salve for Cuts, Bruises, Sores, &c.

Take 1½ oz. of olive oil, 2 oz. of white diacula, and 2 oz. of bees'-wax; let these ingredients be dissolved together, and the salve is formed. This salve I have tried to my satisfaction, and found it answer exceedingly well.

Various Cements.

The joints of iron pipes, and the flanges of steam engines, are cemented with a mixture composed of sulphur, and muriate of ammonia, together with a large quantity of iron chippings.

The putty of glaziers is a mixture of linseed oil and

powdered chalk. Plaster of Paris, dried by heat, and mixed with water, or with rosin and wax, is used for uniting pieces of marble. A cement composed of brick-dust and rosin, or pitch, is employed by turners, and some other mechanics, to confine the material on which they are working. Common paint, made of white lead and oil, is used to cement china-ware. So also are resinous substances, such as mastic and shell-lac, or isinglass dissolved in proof-spirit or water. The paste of book-binders, and paper-hangers, is made by boiling flour. Rice-glue is made by boiling ground rice to the consistence of a thin jelly. Wafers are made of flour, isinglass, yeast, and white of eggs, dried in thin layers upon tin plates, and cut by a circular instrument. They are coloured by red lead &c. Sealing-wax is composed of shell-lac and rosin, and is commonly coloured with vermilion. Common glue is most usually employed for uniting wood and similar porous substances. It does not answer for surfaces impervious to water, such as metals, glass, &c. The cements mostly used in building are composed of lime and sand. The lime adheres to and unites the particles of sand. Cements thus made increase in strength for an indefinite period. Fresh sand wholly silicious and sharp, is the best. That taken from the sea shore is unfit for making mortar, as the salt is apt to deliquesce and weaken the mortar. The amount of sand is always greater than that of lime. From two to four parts of sand are used, according to the quality of the lime and the labour bestowed on it.

An excellent Cement for Paper, Cloth, &c. or for the use of Block-Cutters

In fastening the hatting into the figures, is made by stirring a quantity of raw flour into a rather thin solution of gum-senegal water.

Gilding.

The art of gilding at the present day, is performed either upon metals, or upon wood, leather, parchment,

or paper; and there are three distinct methods in general practice, viz. *wash*, or *water-gilding*, in which the gold is spread, whilst reduced to a fluid state, by solution in mercury; *leaf-gilding*, either burnished or in oil, performed by cementing their leaves of gold upon the work, either by size or by oil; *japanner's-gilding*, in which gold dust or powder is used instead of leaves. Gilding on copper is performed with an amalgam of gold and mercury. The surface of the copper, being freed from oxide, is covered with the amalgam, and afterwards exposed to heat till the mercury is driven off, leaving a thin coat of gold. It is, also, performed by dipping a linen rag in a saturated solution of gold, and burning it to tinder. The black powder thus obtained is rubbed on the metal to be gilded, with a cork dipped in salt water, till the gilding appears. Iron or steel is gilded by applying gold leaf to the metal after the surface has been well cleaned, and heated until it has acquired the blue colour, which at a certain temperature it assumes. The surface is previously burnished, and the process is repeated when the gilding is required to be more durable. It is, also, performed by diluting a solution of gold in nitro-muriatic acid, with alcohol, and applying to the clean surface. A saturated solution of gold in nitro-muriatic acid, and mixed with three times its weight of sulphuric ether, dissolves the muriate of gold, and the solution is separated from the acid beneath. To gild the steel, it is merely necessary to dip it, the surface being previously well polished and cleaned, in the ethereal solution, for an instant, and on withdrawing it, to wash it instantly by agitation in water. By this method steel instruments are very commonly gilt.

Method of Preparing and Using Glue.

Set a quart of water on the fire, then put in about half a pound of good glue, and boil them gently together till the glue be entirely dissolved, and of a due consistence

When glue is to be used, it must be made thoroughly hot, after which with a brush dipped in it besmear the

faces of the joints as thick as possible; then, clapping them together, glide or run them lengthwise one upon another two or three times, to settle them close, so let them stand till they are dry and firm.—Parchment-glue is made by boiling gently shreds of parchment in water, in proportion of one pound of the former to six of the latter, till it be reduced to one quart; the fluid is then strained from the dregs, and afterwards boiled to the consistence of glue. Isinglass-glue is made in the same way; but this is improved by dissolving the isinglass in alcohol, by means of a gentle heat.

China or Indian Ink.

Dr. Lewis, on examining this substance, found that the ink consisted of a black sediment, totally insoluble in water, which appeared to be of the nature of the purest lamp-black, and of another substance soluble in water, and which putrefied by keeping, and when evaporated, left a tenacious jelly, exactly like glue, or isinglass. It appears probable, therefore, that it consists of nothing more than these two ingredients, and probably may be imitated with perfect accuracy by using a very fine jelly, like isinglass, or size, and the finest lamp-black, and incorporating them thoroughly. The finest lamp-black known is made from ivory shavings, and thence called *ivory black.*

Ivory Dyeing.

This substance may be dyed or stained black, by a solution of brass and a decoction of logwood; a green, by a solution of verdigris; a red, by being boiled with Brazil-wood in lime-water.

To prevent the smoking of lamp oil.

Steep your wick in vinegar, and dry it well before you use it.

Portable balls for removing spots from clothes in general.

Take fuller's earth perfectly dried, so that it crumbles to powder, moisten it with the clear juice of lemons,

and add a small quantity of pure pearlash; then work and knead the whole carefully together, till it acquires the consistency of a thick elastic paste: form it into convenient small balls, and expose them to the heat of the sun, in which they ought to be carefully dried. In this state they are fit for use in the manner following: first moisten the spot on the clothes with water, then rub it with the ball just dissolved, and suffer it again to dry in the sun: after having washed the spot with pure water, it will disappear.

Easy and safe method of discharging grease spots from woollen.

Fuller's earth, or tobacco-pipe clay, being first wet on an oil spot, absorbs the oil as the water evaporates, and leaves the vegetable or animal fibres of cloth clean, on being beaten or brushed well. When the spot is occasioned by tallow or wax, it is necessary to treat the part cautiously by an iron on the fire, while the cloth is drying. In some kind of goods, bran or raw starch may be used with advantage.

To take spots out of Silk.

Rub the spots with spirits of turpentine: this spirit exhaling, carries off with it the oil that causes the spot.

To take spots out of Cloths, Stuffs, Silks, Cotton and Linen.

Take one quart of spring-water, put in it a little fine white powder about the size of a walnut, and a lemon cut in slices, mix these well together, and let it stand twenty-four hours in the sun. This liquid takes out all spots, whether pitch, grease, or oil, as well in hats, as cloths and stuffs, silk or cotton, and linen. As soon as the spot is taken out, wash the place with clean water, for cloths of deep colour, add to a spoonful of the mixture, a quantity of water to dilute it.

To render Cloth, wind and rain proof.

Boil together 2 lbs. of turpentine, and 1 lb. of litharge in powder, and 2 or 3 pints of linseed oil. The

article is then to be brushed over with this varnish, and dried in the sun.

A Cement for broken Earthenware.

TAKE 1 oz. of dry cream cheese grated fine, and an equal quantity of quick-lime mixed well together, with 3 oz. of skimmed milk, to form a good cement, when the rendering of the joint visible is of no consequence If mixed without the milk, it perhaps might be stronger still.

To take Mildew out of Linen.

TAKE soap and rub it well; then scrape some fine chalk, and rub that also in the linen; lay it on the grass; as it dries wet it a little, and it will come out at twice.

Soda Water, to make.

TAKE 20 grains tartaric acid, 25 grains super-carbonate of soda: dissolve a lump of sugar, on which you have poured a drop of oil of lemon in two wine-glass-fulls of water: add the tartaric acid: stir it till dissolved. Then dissolve the carbonate of soda in the like quantity of water, and pour the two solutions quickly together, and drink them off as rapidly as possible.

To cure six Hams.

TAKE 6 ozs. of salt-petre, 2 lbs. 10 ozs. of fine salt, 4½ lbs. of brown sugar or 1 gallon of molasses. Rub them with this mixture for one week every day; then put them into a strong pickle (salt and water) for one month; then smoke them, if to keep. Your pickle will, after the hams are taken out, be excellent for beef.

Elastic Cement for Bells.

DISSOLVE in good brandy, a sufficient quantity of isinglass, so as to be as thick as molasses. This composition I am credibly informed answers the purpose remarkably well.

To soften Horn.

Take 1 lb. of wood-ashes, add 2 lbs. of quick-lime, put them into a quart of water, let the whole boil until reduced to one-third,—then dip a feather into it, if the plume comes off on drawing it out, then it is boiled enough; when it is settled filter it off, and in the liquor then strained add shavings of horn, let them soak for three days, then rubbing oil on your hands work the horn into a mass, and print or mould it into whatever shape you want.

Varnish for Harness.

Take ½ lb. of Indian rubber, 1 gallon of spirits of turpentine, dissolve enough to make it into a jelly by keeping almost new milk warm: then take equal quantities of good linseed oil (in a hot state) and the above mixture, incorporate them well on a slow fire, and it is fit for use.

A Varnish for fastening the leather on top rollers in Factories.

Dissolve 2¾ ozs. of gum-arabic in water, and add sc much isinglass dissolved in brandy and it is fit for use.

The manner of soldering Ferrules for Tool-handles, &c.

Take your ferrule, lap round the joining a small piece of brass-wire, then just wet the ferrule, scatter on the joining-ground, borax, put it on the end of a wire, hold it in the fire till the brass fuses. It will fill up the joining, and form a perfect solder. It may afterwards be turned in the lathe.

To make White-wash that will not rub off.

Mix up half a pail full of lime and water, ready to put on the wall; then take ¼ pint of flour, mix it up with water, then pour on it boiling water, a sufficient quantity to thicken it; then pour it, while hot, into the white-wash; stir all well together, and it is ready.

An improved method of tempering Gravers, when too hard.

Having heated a poker red-hot, hold the graver upon it, within an inch of the point, waving it to and fro, till the steel changes to a light straw colour; then, having a piece of steel prepared for the purpose, with two nicks filed in it, one the shape of a lozenge, the other a square graver edge; when heated to a straw colour, put the belly of the graver in one or other of the nicks, as the shape may be, and instead of plunging it into water, tallow, or oil, hammer it on the back-side carefully, till cold, and you will have a far superior tool, if rightly managed, than by tempering the common way. This method closes up the pores of the steel when heated, and renders it more compact; consequently, does not break. It would be well for dentists to manage tools on this principle, for good service and utility.

Easy way of cleaning the Hands, for Dyers, Colourers, &c.

Take a small quantity of pot-ash or pearl-ash in your hand, pour into it a small quantity of water, rub it well all over your hands with a little sand, then wash it off, take in your hand a small quantity of chemic (chloride of lime,) pour a little water into it, and rub it well on the hands in a semi-liquid state; wash the hands well in water, and they will be clean. If not perfectly clean, repeat the operation.

Method of keeping the Hands soft and pliable in all situations.

Rub the hands well in soap till a lather is produced; then rub on a sufficient quantity of sand to let the soap and water predominate; after well rubbing, wash well in warm water. Repeat this two or three times a day, as circumstances may require, and the hands will be kept perfectly soft.

Ink-Powder.

INFUSE a ½ lb. of galls powdered, and 1½ ozs. of pomegranate peels, in a ½ gallon of soft water for a week, in a gentle heat, and then strain off the fluid through a cloth. After which, add to it 4 oz. of vitriol dissolved in a pint of water, and let them remain for a day or two, preparing in the mean time a decoction of logwood, by boiling a half pound of the chips in a half gallon of water, till one third be evaporated, and then straining the remaining fluid while it is hot. Mix the decoction and the solution of galls and vitriol together, and add 2½ ozs. of gum-arabic or the whitest of gum-senegal, and then evaporate the mixture over a common fire to 1 quart, when the remainder must be put into a proper vessel, and reduced to dryness, by placing it in a sufficiently warm place, or letting it hang in boiling water. After the whole of the liquid is evaporated, the residue must be well powdered. When wanted for use, all that is needed, is to dissolve the powder in water.

To give iron a temper to cut porphyry.

MAKE your iron red-hot, and plunge it into distilled water from nettles, acanthus, and pilosella; or in the very juice pounded out from these plants.

To prevent iron from rusting.

WARM your iron till you cannot bear your hand on it without burning yourself. Then rub it with new and clean white wax. Put it again to the fire till it has soaked in the wax. When done, rub it over with a piece of serge. This prevents the iron from rusting afterwards.

To dye in Gold, Silver Medals, or laminas, through and through.

TAKE Glauber salt, dissolve it in warm water, so as to form a saturated solution. In this solution put a small proportionate quantity of calx, or magister of gold. Then

put and digest in it, silver laminas cut small and thin, and let them lay 24 hours over a gentle fire. At the end of this term, you will find them thoroughly dyed gold colour, inside and out.

An oil, one ounce of which will last longer than one pound of any other.

Take fresh butter, quick-lime, crude tartar, and common salt, of each equal parts, which you pound and mix well together. Saturate it with good brandy, and distil it in a retort over a gradual fire, after having adapted the receiver, and luted well the joints.

To make Corks for bottles.

Take wax, hog's lard, and turpentine equal quantities or thereabouts. Melt altogether and stop your bottles with it.

An oil to prevent pictures from blackening. It may serve, also, to make cloth to carry in the pocket against wet weather.

Put nut or linseed oil into a phial, and set it in the sun to purify it. When it has deposited its dregs at the bottom, decant it gently into another clean phial, and set it again in the sun as before. Continue so doing till it drops no more fæces at all. And with that oil, you make the above described compositions.

To gild on Calf and Sheep Skin.

Wet the leather with the white of eggs; when dry, rub it with your hand and a little olive oil, then put the gold leaf and apply the hot iron to it. Whatever the hot iron shall not have touched will go off by brushing.

To dye Wood Red.

Take chopped brazil wood, and boil it well in water, strain it through a cloth. Then give your wood two or three coats, till it is the shade wanted. If wanted a deep red, boil the wood in water impregnated with alum

and quick-lime. When the last coat is dry, burnish it with the burnisher, and then varnish.

Another method to dye Wood Red.

TAKE vermilion and Spanish brown; make them thin with linseed oil and turpentine. Rub it on with a cloth in such a manner as to show the grain of the wood; when dry, varnish. The proportion of vermilion and Spanish brown, must be in proportion to the fineness of the shade wanted.

To imitate Ebony.

INFUSE gall-nuts in vinegar, wherein you have soaked rusty nails; then rub your wood with this; let it dry, polish and burnish.

To produce various undulations on Wood.

SLACK some lime in chamber ley. Then with a brush dipped in it, form your undulations on the wood according to your fancy. And, when dry, rub it well with a rind of pork.

To soften Ivory.

IN three ounces of spirits of nitre, and fifteen of spring-water, mixed together, put your ivory a soaking. And in 3 or 4 days, it will be soft so as to obey your fingers.

To dye Ivory thus softened.

1. DISSOLVE, in spirits of wine, such colours as you want to dye your ivory with. And when the spirit of wine shall be sufficiently tinged with the colour you have put in, plunge your ivory in it, and leave it there till it is sufficiently penetrated with it, and dyed inwardly. Then give that ivory what form you please.

2. To harden it afterwards, wrap it up in a sheet of white paper, and cover it with decrepitated common salt, and the driest you can make it to be; in which situation you shall leave it only 24 hours.

To whiten ivory, even that which has turned a brown yellow.

1. Slack some lime in water, put your ivory in that water, after decanted from the ground, and boil it till it looks quite white.

2. To polish it afterwards, set it in the turner's wheel, and after having worked it, take rushes and pumice-stones, subtile powder with water, and rub it all till it looks perfectly smooth. Next to that, heat it by turning it against a piece of linen, or sheep-skin leather, and when hot, rub it over with a little whitening diluted in oil of olive; then with a little dry whitening alone, and finally with a piece of soft white rag. When all this is performed as directed, the ivory will look remarkably white.

To whiten Bones.

Put a handful of bran and quick-lime together, in a new pipkin, with a sufficient quantity of water, and boil it. In this put the bones, and boil them also till perfectly freed from greasy particles.

To petrify Wood, &c.

Take equal quantities of gem-salt, rock-alum, white vinegar, chalk, and pebbles powder. Mix all these ingredients together: there will happen an ebullition. If, after it is over, you throw in this liquor any porous matter, and leave it there a soaking four or five days, they will positively turn into petrifactions.

A preparation for Tortoise-shell.

Take orpine, quick-lime, pearl-ashes, and aquafortis. Mix well altogether, and put your horn or tortoise-shell in it to soak.

To dye Bones any colour.

Boil the bones first for a good while; then in a ley of quick-lime mixed with chamber ley, put either verdigris, or red or blue chalk or any other ingredient fit to pro-

cure the colour you want to give to the bones. Lay the bones in the liquor, and boil them, they will be perfectly dyed.

To write on Silver with a black which will never go off

Take burnt lead, and pulverize it. Incorporate it next with sulphur and vinegar, to the consistency of a painting colour, and write with it on any silver plate. Let it dry, then present it to the fire so as to heat the work a little, and it is finished.

To restore Wine that is turned sour or sharp.

Fill a bag with leek-seed, or of leaves or twisters of vine, and put either of them to infuse in the cask.

To correct a bad taste and sourness in Wine.

Put in a bag the root of wild horse-radish cut in bits. Let it down in the wine, and leave it there two days: take this out, and put another, repeating the same till the wine is perfectly restored. Or fill a bag with wheat: it will have the same effect.

To cure those who are too much addicted to drinking Wine.

Put in a sufficient quantity of wine, three or four large eels, which leave there till quite dead. Give that wine to the person you want to reform, and he or she will be so much disgusted with wine, that though they formerly made use of it, they will now have an aversion to it.

To increase the sharpness and strength of Vinegar.

Boil two quarts of good vinegar, till reduced to one; then put it in a vessel and set it in the sun for a week. Now mix the vinegar with six times its quantity of bad vinegar in a small cask: it will not only mend it, but make it strong and agreeable.

To make Vinegar with water.

Put 30 or 40 lbs. of wild pears in a large tub, where you leave them three days to ferment. Then pour some

water over them, and repeat this every day for a month at the end of which it will make very good vinegar; the goodness of which may be increased by the above method.

A dry portable Vinegar.

Wash well half a pound of white tartar with warm water, then dry it, and pulverize as fine as possible. Soak that powder with good sharp vinegar, and dry it before the fire or in the sun. Re-soak it as before with vinegar, and dry it as above, repeating this operation a dozen of times. By these means you will have a very good and sharp powder, which turns water instantly into vinegar. It is very convenient to carry in the pocket, especially when travelling.

How to extract the essential oil from any flower.

Take any flowers you like, which stratify with common sea-salt in a clean earthen glazed pot. When thus filled to the top, cover it well, and carry it to the cellar. Forty days afterwards put a crape over a pan, and empty the whole to strain the essence from the flowers by pressure. Bottle that essence and expose it 4 or 5 weeks in the sun, and dew of the evening to purify. One single drop of that essence is enough to scent a whole quart of water.

To make Mutton Suet Candles, in imitation of Wax.

1. Throw quick-lime in melted mutton suet; the lime will fall to the bottom, and carry along with it all the dirt of the suet, so as to leave it as pure and as fine as wax itself.

2. Now if to one part of the suet, you mix three of real wax, you will have a very fine, and to appearance a real wax candle, at least the mixture could never be discovered, nor even in the moulding way for ornaments.

RECEIPTS ON DYEING.

General remarks on Dyeing.

Cleanliness in dyeing is very essential. The vessel and the articles to be dyed, must be ridded of grease and dirt; as grease resists the colouring particles, and dirt leaves a stain.

Soft water should always be used for dyeing. Vessels used for dyeing small articles, should generally be wash hand basons, small copper and tinned pans, and sufficiently large that the dyeing liquor be not spilt by dipping the article in and out when dyeing.

The quantity of liquor generally necessary for dyeing a dress of muslin, crape, sarsnet, cambric, &c. is about three quarts; for a larger dress a proportionable quantity.

The dyeing utensils are simple, being composed of tubs, kettles, horse, or a couple of lathed benches, for the purpose of placing the goods upon, when they come from the dye. The horse may be in form of a carpenters' stool. A doll which is used for beating blankets, counterpanes, &c. in the tub in order to clean them. For this doll some use an article similar to a pavior's mall, but of smaller dimensions: others have a circular piece of wood 2 inches thick, in which 4 legs are fastened, on the under side, and in the centre a pretty long handle, with a cross piece put through it to work it with. Against the wall or a post, fasten a hook or pin to put on your skeins, and with a small stick wring them out. In fancy dyeing the various shades of cambric, a winch is in frequent use.

The liquors should always be stirred with a spoon, rod, or any thing that is clean, previous to the article being dipped in it, to cause the colouring particles to be equally diffused, so that the article to be dyed receives its colour uniformly, and it is also necessary that the article be moved in and out quick, and opened to receive the colour more evenly

Colours generally look much darker when wet, therefore, allowance should generally be made for drying, which should always be done in a warm room, pinned or tretched to a line.

(1.) *Aluming*

Is a preparation necessary for some colours in order to receive the colouring particles, such as crimson, scarlet, purple, and some other colours. If any article is directed to be alumed, be careful to rid it well of the soapsuds, as alum turns soap to grease. When the article is put in the alum liquor, it is to be well dipped in and out, and opened, to receive this preparation more equally, for an hour, or all night if circumstances admit, and when alumed, it must be well wrung out, and rinsed in two waters, and then dyed, the sooner the better, before getting dry. NOTE.—The aluming of silks ought to be done cold, or it will be deprived of its lustre.

(2.) *Preparing of the dye-liquors, or scalding the woods.*

HAVING something like the end of a tub, about one foot deep, with a copper bottom, bored full of holes about a quarter of an inch in diameter; lay a piece of rather coarse sheeting on this, lay it altogether on another tub; fill it with the wood to be scalded; then having a copper-boiler full of boiling water, fill the tub which contains the wood with boiling water, stir it during the time it is going through; fill it up again, and so repeat the operation till you have got all the strength from the wood. The criterion by which to know when the strength is gone from the wood, is the paleness of the liquor as it runs through. This operation is considered superior to boiling the wood in a copper-boiler, especially for the ground-woods; but either way will answer. The method of rendering the liquor stronger, of course, is by evaporation, in a copper-vessel, with a constant fire under it. The chips of dye-woods are generally superior to the ground-woods, as they are not so likely to be adulterated.

(3.) *Pink on Silk.*

After aluming, (see receipt No. 1.) handle the goods to be dyed in peach-wood liquor, till the colour desired; then take out and put in a little alum liquor, handle the goods a little longer, take out, rinse in water, and finish. Note.—In most cases, where the shade is not dark enough, the operation must be repeated.

(4.) *Brown on Silk:*

Alum your silk: (see No. 1.) Then take one part of fustic liquor, and three parts of peachwood liquor; handle in these till it becomes a good brown; (a little log-wood liquor will darken your shade, if required,) hedge out, and put in a little alum-water; again put in your goods, handle a little longer, then take out, drain, rinse well, and finish. Note.—By varying the peachwood and fustic, various shades may be obtained.

(5.) *Green on Silk.*

Take green ebony, boil it in water, let it settle; take the clean liquor as hot as you can bear your hands in it, handle in it your goods till of a bright yellow; then take water, and put in a little sulphate of indigo; handle your goods in this till of the shade wanted. Note.—The ebony may previously be boiled in a bag, to prevent it from sticking to the silk.

(6.) *Sulphate of Indigo.*

Take 3 lbs of vitriol, 1 lb. of ground indigo; put in a little at a time, and keep stirring till all dissolved. Let stand 24 hours, and ready.

(7.) *Blue on Silk.*

Indigo, same as No. 5, green; you will have a blue. Note.—The silk ought to be boiled in white soap and water, and made quite white, and then rinsed in luke-warm water.

(8.) *Black on Silk.*

TAKE 1 oz. of bluestone of vitriol, 2 oz. of copperas, ½ oz. of nitrate of iron; mix all together with as much water as will do one piece; have the water a little warm; hedge in this six times, backward and forward, take out, rinse in water; take another tub, put in it as much logwood liquor, that has in it 1 lb. of logwood, 1 oz. of fustic liquor; hedge in this liquor with a sufficient quantity of water, till black; wash out, and finished.
NOTE.—In both processes, let them have a chance to air in drying.

(9.) *Blue Black on Silk.*

FIRST run through a mordant of nitrate of iron and water, then run through pearl-ash water, then through nitrate of iron again; then put them through logwood liquor, with a little bluestone of vitriol dissolved in it. If not dark enough, repeat the operation.

(10.) *Maroon on Silk.*

To 3 lbs. of silk, take ½ lb. of Cudbear, put it in water, let it boil, then put in your silk, let it boil a few minutes, keep your silk well handled, take out, and you will have a good handsome colour. To change the shade, put in 2 lbs. of common salt; operate as before: this will vary the shade. To vary it still further, take the silk, after boiling it the first time without the salt, handle it in pearl-ash water, or in cream of tartar, and you will have a handsome blue.

(11.) *Orange on Silk or Cotton.*

TAKE 1 lb. of silk, 1 oz. of arnotta, 2 oz. of pearl-ash, boil them well together, turn in your goods; when boiled 10 minutes, take out, wash, and finished.

If this orange is dark, handle the goods at hand-heat.

NOTE.—These goods must be well washed out in soap, and in aluming them, you may use a little sugar of lead

(12.) *Grey on Silk.*

For a silk dress. Take 4 or 6 oz. of fine powdered galls, pour on them boiling water, handle your silk in this for 20 or 30 minutes; in another form, dissolve a piece of green copperas, about the size of a nut; handle your silk through this, and it will be a grey, more or less dark according to the quantity of drugs.

(13.) *Slate on Silk.*

To make a slate, take another pan of warm water and about a tea-cup full of logwood liquor, pretty strong, and a piece of pearl-ash, of the size of a nut; take the above grey-coloured goods, and handle a little in this liquor, and it is finished. NOTE.—If too much logwood is used, the colour will be too dark.

(14.) *Olive on Silk.*

BY adding a little fustic liquor to the above slate, it will form an olive: it may be necessary to run them through a weak pearl-ash water to sadden them. Wash in two waters for the above three colours. They will keep their colour very well.

(15.) *Stone colour on Silk.*

TAKE the coloured grey (see receipt No. 12.) Add a sufficient quantity of purple archil to the grey liquor. To give them a red sandy cast, add a little red archil: simmer the silk in this a few minutes. Rinse in one or two cold waters. Dry in the air. The red archil is made from purple archil, by adding a small quantity of vitriol and water, which will redden it.

(16.) *To dye a Silk Dress Brown.*

TAKE 8 oz. of sumach; 4 oz. of logwood; 8 oz. of camwood or madder; boil these drugs in water, then cool down your liquor; wet out your silks; then enter them; handle well; wash out as usual. For a mulberry cast, add as much purple archil as may be necessary.

(17.) *Drab on Silk.*

For a silk dress. Take 4 oz. of archil, one oz. of madder; enter and handle the goods; this may be saddened, by taking out your goods and dissolving in the liquor a piece of green copperas, the size of a nut; again handle in this liquor; or, what is still better, instead of copperas, use a little pearl-ash to sadden with.

(18.) *Dove on Silk.*

Take Brazil logwood and sumach; vary the quantities as you want your shade; boil them in water, then enter your goods, handle well, and sadden with green copperas.

(19.) *Yellow on Silk.*

Boil quercitron barks in a copper pan for 20 minutes, any quantity you please. Dip out a sufficient quantity to cover your silk, in another copper pan, or tinned vessel, into which add a small quantity of muriate of tin; pass your silks first through warm water, and wring them out; then put them into this pan of dye-water, and handle them with a clean stick, till cold; when cold, take out, throw out your liquor, take from the first pan as much liquor as before, handle in this 10 minutes, then add muriate of tin according to shade wanted. Rinse out in its own liquor and dry in a warm room. Annetto affords an orange yellow with equal quantities of pearl-ash, and gives out its colour to silk in warm water. Turmeric gives out its colour in a similar manner. The roots of Barbary afford a yellow of themselves, when boiled in water.

(20.) *Crimson on Silk.*

Take Cudbear, boil it in water; then just rinse or handle your silks in it for a few minutes, you have the shade wanted. Chamber ley or any alkaline solution will change the colour.

(21.) *Flesh Colour on Silk.*

Having first thoroughly cleaned your silk in the usual manner, rinse in warm water; then handle them in a

very slight water of alum and tartar, so slight that you could hardly taste it. Then if you have been dyeing Pinks, No. 3, receipt, take some of the old liquor, handle in it till of the shade wanted. The liquor must not be too strong, or the shade will be too heavy.

(22.) *Brown on Woollen Cloth, or Clothes of any description.*

The quantity of woods to be regulated according to the quantity of goods to be dyed. For instance, a pair of men's pantaloons, being first well cleaned from all grease: take 1 lb. of red-wood, hypernick, or peach-wood; 1 lb. of fustic, put them in a copper kettle, boil them, then cool down so as to bear in it your hand; then put in a small quantity of cream of tartar, agitate the water; then enter your goods, handle them till they come to a boil, let it boil 5 or 10 minutes; take out the goods, put in a strong solution made of 4 oz. of copperas, again cool down, re-enter the goods, again bring them to a boil; take out, rinse well in water, finished.

This process makes a good substantial brown, and might be varied in the shade by varying the quantities of woods in their proportion, also, by adding a little alum in the saddening. This is somewhat of an olive cast.

(23.) *A Brown on the Red cast.*

Take 2 of red-wood, 1 of fustic, proceed in every respect as in No. 22, receipt, the desired shade will be required. The quantity of dye-woods may be regulated according to the quantity of goods to be dyed, in No. 22, also, the copperas and tartar. On woollen of course.

(24.) *Olive Brown.*

For a pair of pantaloons, providing they weigh 3 lbs.; take 1 lb. of fustic, 1 oz. of logwood, 4 oz. of common Madder, 2 oz. of peachwood; boil them up, then cool down your liquor, enter your pantaloons, bring the liquor to a boil, let it boil half an hour, occasionally turning

over; take out, cool down your liquor, put in 2 oz. of dissolved copperas, handle until deep enough. For wool: Any quantity of yarn may be dyed on the same principle.

(25.) *A Brown inclining to Snuff.*

Take any quantity of woollen goods, use for every lb. 1½ or 2 lbs. of logwood; first put your logwood into the copper vessel, bring it to a boil; cool down, then enter your goods, bring them to boil, half an hour or longer, if a large quantity; take out, wash and finished. Put, however, a little sumach, about 2 oz. to the lb. of logwood. This will be a good shade of brown. To alter this shade, put into your liquor a proportionally small quantity of alum liquor, again enter the goods, you will have a good handsome shade on silk, as well as woollen.

(26.) *A Black inclining to Purple on Wool and Silk.*

Take 4 lbs. of logwood, 1 lb. of sumach, boil them in a sufficient quantity of water; cool down with water enough to dye 4 or 5 lbs. of silk or wool; enter the goods, bring them to boil, for ten minutes; take out, partly cool down, put in about 1 lb. of copperas; again enter your goods, bring them to a boil, take out, wash and finish. Chiefly intended for wool.

N. B. A pair of pantaloons or any other article which is old, would not need to be so particular in quantity of dye-stuffs, nor length of time. It will also answer for cotton, and that without sumach, if the sumach is not at hand. This is intended chiefly for woollen.

(27.) *A Black inclining to Brown on Silk and Woollen.*

Take one part of sumach, one of logwood, one of hypernick or peachwood; boil the dye-stuffs, cool down; put in the silk or woollen according to the quantity of your dye-woods, bring them to a boil, for ten minutes, take out the goods, cool down; having put in a sufficient quantity of dissolved copperas, again enter the goods bring to a boil, take out, wash well and finish.

To mix the copperas with alum would materially alter the shade, if a variety was wanted. This is chiefly intended for wool.

(28.) *A Jet Black on Woollen or Woollen Cloth.*

For 7 lbs. of wool or woollen cloth, take 3½ lbs. of logwood, ¾ lb. of sumach, ¾ lb. of fustic; boil these drugs in a sufficient quantity of water for 20 minutes, cool down, put in your goods, bring to a boil half an hour, then take out, cool down your liquor; add copperas dissolved in water 1¼ lbs., blue stone of vitriol 2 oz.; again enter your goods, bring to a boil 15 minutes, take out, wash well in cold water, and finish.

(29.) *Blue Prussian on Woollen.*

Take any quantity of calcined copperas, dissolve it in warm water, strong, put in your goods, keep them well handled till the water comes nearly to a boil, still handle 15 minutes; then rinse the goods in cold water; get up another kettle of 1 of urine to 3 of water, bring the water to hand heat; put in your goods, handle half an hour; again rinse in cold water; get up another kettle of water, hand heat, and for each lb. of goods 3 oz. of prussiate of potash, put some oil of vitriol in the kettle, handle the goods half an hour, if the colour looks green, add a little more vitriol, handle half an hour longer, take out, wash in cold water, and finish.

(30.) *Green on Wool.*

For 6 lbs. of yarn, worsted, or cloth, take 3 lbs. of fustic, ¾ of alum; boil them in a kettle 10 minutes, partly cool down; then put in a small tea-cup full of sulphate of indigo, rake it well up, enter your goods, bring up to a boil, keeping the goods well handled, let boil 20 minutes, (if a larger quantity, boil longer in proportion,) take out, and if not blue enough, add a little more sulphate of indigo; handle until deep enough. Rinse in cold water, and finish.

This shade may be altered in a variety of ways, by adding a little camwood, or logwood, in the first boiling.

(31.) *Lilac on Wool.*

Boil up any quantity of archil, according to the quantity of goods you want to dye; cool the liquor a little, enter the goods, handle carefully, until the shade is deep enough, without boiling the liquor, take out, wash, and finish. 1 lb. of archil will dye $4\frac{1}{4}$ lbs of goods. Silk may be dyed in the same way. The shades may be altered by soda, pearl-ash, wine, or common salt, adding a little, and re-entering the goods before washing, and handling a little while longer.

(32.) *Drab on Woollen.*

For about 15 lbs of woollen goods, take $\frac{3}{4}$ lbs of weld, 9 oz. of madder, 4 oz. of logwood, 3 oz. of archil; put them in water, bring them to a boil for 10 or 15 minutes, cool down, enter the goods, boil 15 minutes, wind up; put in 1 oz. of alum, $1\frac{1}{2}$ oz. of copperas, ground; boil a few minutes longer, during which time, handle well; take out, wash, and finish. The above receipt may serve as a standard of procedure for all the drab shades, which may be altered at pleasure, that can be produced; only varying the quantities of drugs, in some cases adding archil, and in others, a little sulphate of indigo. Red tartar and camwood may also be used. The copperas and alum may be varied in quantity, or increased, or the alum left out; thus varying the whole round.

(33.) *Red on Woollen.*

For 10 lbs. of woollen goods. Take 2 lbs. of alum, $\frac{1}{2}$ lb. of red tartar; boil the goods in this 1 hour; (if a larger quantity of goods boil longer time) then boil up $4\frac{1}{2}$ lbs. of peachwood in clean water, cool down to a scald, put in 2 oz. of No. 1, tin liquor, enter the goods, handle until dark enough, and finish. The goods must not be washed between the 1st and 2d operation.

(34.) *Slate on Woollen.*

For 10 lbs. of woollen goods. Take 10 lbs. of sumach, boil it up 10 minutes, cool down, put in your goods, bring them to a boil a few minutes, take out, put in 4 lbs. of copperas, dissolve, cool down; re-enter the goods, bring them to a boil, take out, wash and finish. A quantity of iron liquor, such as the calico-printers use, would be preferable to copperas. This slate may be varied by varying the proportion of copperas and sumach; also, by adding a little peachwood, or any other red-wood; in this case, less copperas might be used.

(35.) *Yellow on Wool.*

For 10 lbs. of wool. Bring a kettle of water to a scald or 180 degrees of heat, put in 4 lbs. of quercitron bark, (do not allow it to boil, as that would fetch out the tanning and dull the yellow) 1 lb. of alum, 6 oz. of cream of tartar, nearly a half pint of No. 1, tin liquor; stir up the liquor well, allow it to settle 15 minutes; enter the goods, keep in until dark enough.

(36.) *Orange on Wool.*

First dye the pattern to a full yellow. Then take a clean kettle of water, when a little warm, put in for the above goods 2 lb. of madder, peachwood, mongeat, or hypernick; mongeat does very well: put in your goods, keep them well handled, bring the goods to a boil, let boil till dark enough, wash and finished.

VARIOUS SHADES OF FANCY DYEING ON COTTON.

(37.) *For any quantity of Thread in Black.*

First take the thread, boil it in sumach and water; then let it be immersed in lime-water, cold; then in weak copperas water, cold; then in lime-water again, cold; then in logwood liquor, warm; take out, put some copperas liquor into your logwood liquor, again put in your goods, handle and finish. This makes a first-rate black.

(38.) *Turmeric yellow.*

Take about 3 lbs. of turmeric, put it in a small tun for the purpose, pour on it a tumbler of oil of vitriol, stir it well up, then pour on it hot water, about two gallons, stir this well up; then having half a tub-full of water, boiling hot from the boiler, pour on it the contents of the small tub; enter three pieces, 30 yards each, give them 6 or 8 ends, as the workmen term it, fold up; the next process, have another tub of water, put in it half a pale full of alum liquor, give the pieces 3 or 4 ends in this, take out and finish. Renew with the same quantity for the next 3 pieces, and so proceed. Note.—By the ends is meant rinsing the pieces backward and forward over the wince in the tub. A half a hogshead will answer the purpose.

It will be understood that these cotton colours are intended for linings or cambrics. It will also be understood that the liquors must be prepared as in receipt, No. 2, or by boiling in a copper-cistern; the former is most generally adopted for this kind of dyeing. It will be necessary to have a number of tubs for the different liquors; and in dyeing various shades, to have the liquors prepared in readiness.

(39.) *Green on Cotton.*

Take as much hot fustic liquor as will cover 3 pieces, in which is put a very little lime liquor, put it in a tub, enter your goods, give them 5 ends, hedge them out; take another tub, half full of water (cold), put into it a sufficient quantity of blue-stone of vitriol liquor, to set the tub, about two quarts, enter your goods in this, give them five ends, hedge out, then take a couple of pail-fulls of the fustic liquor, renew the first tub, enter 3 pieces more, and so proceed as at first; then renew your blue vitriol tub with half the quantity of liquor, not taking any out, and proceed as at first. In this way do as many the first and second time, as you can finish that day; then commence to finish them. Take half a tub

full of old fustic liquor that has been used once, and put to it 1½ pail-fulls of logwood liquor; enter your pieces 3 at a time, give them five ends, and finish. Renew with a little more logwood liquor, enough to make them dark enough, having first thrown away a couple of pail-fulls from the tub, and renew with the same from the old tub, and so proceeed in finishing.

(40.) *Buff on Cotton.*

Take as much hot fustic liquor and water, as will half fill a tub, enter 3 pieces, give them 5 ends, hedge out; take another tub of lime-water cold, enter the same pieces, and give them 5 ends in this, take out, and in a short time they will be buff. Renew your first and second tub, and proceed as at first. This is all required for buff.

(41.) *Annetto Orange on Cotton.*

Having prepared your annetto liquor by boiling it in a copper vessel for 20 minutes; take out your liquor, put it in a tub; partly fill your boiler with water, bring it to a boil, having kept in the boiler the sediment of the annetto, make it strong enough with annetto liquor, to the shade you want to dye; enter 3 pieces when boiling, give them 3 ends, take out; enter them into cold alum water, give them 4 ends, take out and finish. Renew your annetto boiler with a sufficient quantity of annetto liquor, and proceed as before; then renew your alum tub, proceed as before in the 2d process. This finishes them.

The liquor that is left in the boiler at night, will do to boil the annetto in the next day, so that nothing is lost.

(42.) *Red on Cotton.*

Take 3 pieces, enter them into a tub with hot red-wood, or peach-wood liquor, give them 5 ends, then run them into your wince; have another tub called the spirit tub close by, half full of cold water, put into it about 3 tumblers full of spirits; then run the pieces from the

other wince over the wince of the spirit tub, give them 5 ends in the spirit tub, then wind them on the wince of the spirit tub, then back again to the red tub; give them 5 ends without having renewed the tub, they are finished.

Throw away the red tub liquor, put in fresh liquor, and proceed as before; but the spirit tub must be renewed always; even at night it may be left in a tub, and renewed the next day.

(43.) *Brown on Cotton.*

The first process is to give them 5 ends in hot sumach liquor, or let them lay all night in the large tub, same as for blacks; then give them 5 ends in copperas, hedge out, give them 5 ends in lime tub; then hedge out, lay them one side till you get enough to finish that day. You next renew your tubs and repeat the operation as before. Then comes the finishing part. Make up a tub of hot red-wood liquor; enter 3 pieces, give them 5 ends, put the pieces one side the tub, put in some alum liquor, stir up, give them 5 ends more, hedge out and finished.

(44.) *Drab on Cotton.*

Take half a tub of hot sumach, and fustic liquor; more fustic than sumach, according to shade wanted; enter 3 pieces, give them 5 ends, hedge out; give them 5 ends in the copperas tub, and finished. Renew your tubs, and proceed as before. The copperas tub is a half a tub of water, with a couple of pail-fulls of copperas liquor to set it in the first place; renewed each time.

(45.) *Slate on Cotton.*

Make up a tub of about 2 of logwood to one of fustic liquor, both hot; enter 3 pieces, give them 5 ends, hedge out; give them 5 ends in copperas liquor; have it stronger or weaker according to shade wanted. This finishes them. Renew your tubs, and proceed as before.

(46.) *Purple on Cotton.*

Get up a tub of hot logwood liquor, enter 3 pieces give them 5 ends, hedge out; enter them into a clean alum

tub, give them 5 ends, hedge out; get up another tub of logwood liquor, enter, give them 5 ends, hedge out; renew your alum tub, give them 5 ends in that, and finish

(47.) *Black on Cotton.*

First take your pieces and boil them in sumach liquor, in a large copper vessel, if you have it, that will hold 60 or 70 pieces, in which you put about a bushel and a half of sumach; let them stay all night if it is convenient; take out, and enter them into the lime-tub, 3 at a time, give them 4 ends, hedge out; enter them into the copperas tub, give them 5 ends, hedge out; enter them into the lime again, give them 4 ends, hedge out; enter them into another tub with tolerably strong logwood liquor, give them 5 ends; put them to one side of the tub, put in enough of copperas liquor to blacken them, (about a couple of quarts,) then give them a few more ends, and they are finished. With this process, it is the same as with the greens. After sumaching, liming, copperassing, and second lining is repeated, till you get as many as will answer you to finish that day, the tubs being renewed after each 3 pieces: then comes the finishing; after each 3 pieces, the logwood and copperas-liquor is thrown away, because the copperas kills the logwood, and so renders it unfit for the next pieces. It is frequently the case, that instead of the first process of sumach boiling, they collect the old sumach, and fustic, and logwood liquor, that has no copperas or lime in it, into a large tub, and all the pieces that are spoiled in the other colours, they throw them into this tub, let them lay a few days till they are ready to dye blacks, and this answers instead of the sumaching.

For the foregoing cotton shades, the pieces are first taken and boiled in a wood or copper cistern, as circumstances may be, in order to take out the sizing, and prepare them to receive the dye.

(48.) *To put a fine gloss on Silk.*

Take a fair white potato, cut it in very thin slices, pour on it boiling water, let stand till rather cool, take

out the slices of potato, run your silk through this water squeeze out, smooth while damp, and you will have a very superior gloss. I tried this on black silk, and found it to answer well. If it should not answer on lighter colours, try the following one. If a quantity of silk, of course proportion your potatos.

(49.) *Another way*

Instead of a potato, use a small quantity of isinglass, dissolved in water. Use it the same as the above in every particular, one oz. of isinglass will answer 1 lb. of silk.

(50.) *Names of the principal Dyeing Materials.*

Alum, argal, or tartar, green copperas, verdigris, blue vitriol, quercitron, and oak bark, mahogany-sawdust, with acetate of alumine, mordant forms a good orange inclining to flesh colour; fenugreek, logwood, fustic, Brazil wood, braziletto, camwood, barwood, and all other redwoods, peachwood, sumach, galls, weld, madder of various kinds, safflower, savory, green ebony, annatto, turmeric, archil, cudbear, cochineal, lac-dye, indigo, and tarzabonica or catecheu. This last drug, is now used extensively in colour-making and dyeing, treated with sal ammoniac, pearlash, bicromate of potash, &c.

(51.) Pearlash mordant, with walnut husks, produces a nankeen.

(52.) *No.* 1, *Tin Liquor.*

Take 2 quarts muriatic acid; killed with 24 oz. of granulated tin. This will answer for woollen, or cotton

(53.) *No.* 2, *Tin Liquor for Yellows on Woollen.*

About 4 parts of muriatic to one of sulphuric, killed with granulated tin. This will answer for yellow on cotton also.

(54.) *Tin Liquor for Pinks, Scarlets, Crimson, &c.*

1 Of muriatic, 1 of nitric acids, killed with tin.

(54.) *Tin Liquor, for Scarlet, Crimson, &c. on Silk.*

TAKE 1 lb. of nitric, and 1 lb. of muriatic acids; about 1½ oz. of sal ammoniac; kill with granulated tin.

(55.) *The manner in which the French Madder is marked according to quality.*

FIRST quality marked E. K. F. 2d Quality E. S. F. F. 3d Quality S. F. F. 4th Quality S. F.

(56.) *To set an Indigo Vat for Cotton.*

HAVING a sufficiently large vat, nearly fill it with water, put in 30 lbs. of ground indigo, 50 lbs. of copperas, 50 lbs. of slacked lime; occasionally stir it up for two days. When perfectly settled, it is ready for use. When the vat is exhausted, renew with 4 lbs. of pearlash, 4 lbs. of lime, and 12 lbs. of copperas.

(57.) *A Blue Vat for Silk and Woollen.*

TAKE 8 lbs. of indigo, about 2 gallons of vinegar, work it in the mill till fine; if this is not convenient, put them on a slow fire for 24 hours, till dissolved; put in 1 lb. of madder, mix these well, and put them into a vat containing 100 gallons of urine, stir well twice a day, for 1 week. It may then be worked, always previously stirring it. This vat continues to be good till exhausted. Nazarine blues, and deep purples, may be managed with this vat and archil dye, taking care to rinse it well from one to the other. Archil forms a dye of itself without mordant, on silk and woollen, when boiled in water.

(58.) *To dye Straws Red.*

BOIL ground Brazil-wood in a ley of potash, and boil your straws in it.

(59.) *Blue on Straw.*

TAKE a sufficient quantity of potash-ley, 1 lb. of litmus, or lacmus-ground, make a decoction of, and then put in the straw, and boil it.

(60.) *Turkey-red on Leather.*

After the skin has been properly prepared with sheep, pig's-dung, &c., then take strong alum-water, and sponge over your skin; when dry, boil a strong gall liquor, (it cannot be too strong;) then boil a strong Brazil-wood liquor, the stronger the better; take a sponge, dip it in your liquor, and sponge over your skin; repeat this, till it comes to a full red: to finish your skin, take the white of eggs and a little gum-dragon, mix the two together in half a gill of water, sponge over your skin, and when dry, polish it with a bottle, or piece of glass prepared for the purpose.

(61.) *Yellow on Leather.*

Infuse quercitron bark in vinegar, in which boil a little alum, and brush over your skins with the infusion finish same as the red.

(62.) *Another Yellow.*

Take a pint of whiskey, 4 oz. of turmeric; mix them well together; when settled, sponge your skin over, and finish it the same way as the red.

(63.) *Blue on Leather.*

For each skin, take 1 oz. of indigo; put it into boiling water, and let it stand one night; then warm it a little, and with a brush, smear the skin twice over, finish same as the red.

(64.) *Black on Leather.*

Put your skin on a clean board, sponge it over with gall and sumach liquors strong, then take a strong logwood liquor, sponge it over 3 or 4 times; then take a little copperas, mix it in the logwood liquor, sponge over your skin, and finish it same as the red.

(65.) *Different Shades on Leather.*

The pleasing hues of yellow, brown, or tan colour, are readily imparted to leather by the following simple pro-

cess. Steep saffron in boiling water for a number of hours, wet a sponge or soft brush in the liquor, smear the leather. The quantity of saffron, as well as of water, will of course depend on how much dye may be wanted, and their relative proportions on the depth of colour required.

(66.) *To dye Leather purple.*

First sponge the leather with alum liquor strong, then with logwood liquor strong, or mix them both and boil them, and sponge with the liquor: finish same as for red.

A

SUPPLEMENT

TO THE

ARTIST'S GUIDE

AND

MECHANIC'S OWN BOOK.

WITH

PRACTICAL RULES AND TABLES

FOR

ENGINEERS, MILLWRIGHTS, MACHINE MAKERS, CARPENTERS, BRICKLAYERS, SMITHS, &c

CONNECTED WITH

THE STEAM ENGINE, WATER WHEELS, PUMPS, AND MECHANICS IN GENERAL.

ALSO,

THE STEAM ENGINE RENDERED EASY,

IN A SEPARATE TREATISE, WITH PLATES.

TO WHICH IS ADDED,

THE MANAGER'S ASSISTANT IN A COTTON MILL,

FROM THE RAW MATERIAL INTO YARN AND CLOTH.

ALSO,

A Corresponding Scale of Beaume and Twedale's Hydrometer compared with Specific Gravity, useful for Calico Printers, Dyers, Bleachers, &c.

BY JAMES PILKINGTON.

BOSTON:
SANBORN, CARTER AND BAZIN.
PORTLAND:
SANBORN & CARTER.
1856.

STEAM ENGINE.

I TRUST I shall not be thought impertinent, and, I hope, not partial, in recommending one of the latest, and I may safely say, the best improvement as yet known, for the economical using of fuel; it is Mr. Brunton's Fire Regulator. This machine feeds the fire in the most regular manner, and nicely proportions the quantity of coal thrown upon the grate, to the quantity of steam required.

Almost the whole of the public works using steam engines in London, have this Fire Regulator attached to their boilers. And the accounts kept by their engineers, of the quantity of coal consumed, exhibit a saving of from 15 to 25 per cent. produced by it. But the regular manner of feeding the fire, and, consequently, the saving of fuel, are not the only advantages derived from it. There is no regular fireman needed, the hopper only requires to be filled with coal in the morning, and no other attendance is necessary; also the supplementary boiler, which is attached to the large boiler, gives an additional quantity of steam, say from 2 to 6 horses, in proportion to the size of the engine, and preserves the large boiler from the injurious effects of the fire.

These advantages, derived from this Fire Regulator over the usual mode of feeding the fire by hand, make it one of the most useful inventions of the present day, and, in fact, a steam engine is not complete without it.

Since the last edition of the Compendium was published, Mr. Brunton has added a further improvement to his Fire

Regulator, by which he is enabled to apply it immediately under round boilers or stills.—In this improved state it is now at work under the stills of Messrs. Thomas Smith & Co. Whitechapel Distillery, who find it to effect a very considerable saving in fuel and attendance.

Boilers—are of various forms, but the most general is proportioned as follows, viz. width 1, depth 1.1, length 2.5; their capacity being, for the most part, two horse power more than the power of the engine for which they are intended. These are the proportions of the wagon boilers, but the cylindrical boiler with a flue through it, is now frequently used, and is much the stronger boiler; it is also better adapted than the other for quickly generating steam, there being more heating surface exposed in proportion to the volume of water;* but for a stationary engine that is daily employed, the elliptical boiler is preferable; it contains a greater body of water than the cylindrical, and though the steam cannot be got up so expeditiously, yet, when it is up, it can be kept at a more uniform pressure, being less susceptible of any variation in the temperature of the furnace.

Boulton and Watt allow 25 cubic feet of space for each horse power, some of the other engineers allow 5 feet of surface of water.

Steam—arising from water at the boiling point, is equal to the pressure of the atmosphere, which is, in round numbers, 15 libs on the square inch; but to allow for a constant and uniform supply of steam to the engine, the safety valve of the boiler is loaded with 3 libs on each square inch.

Where boilers are in good order and sufficiently strong, it is advisable to use steam at a pressure of 10 libs instead of 3 libs, as stated above. Steam at this pressure is, consequently, much more effective, and the engine performs its work with greater ease; but to use steam of this pressure,

* Common pressure boilers ought to expose, for each horse power, 12 square feet of surface to the heat of the furnace—and about $\frac{1}{4}$ of a square foot of grate surface for one horse.

the feed pipe of the boiler requires to be lengthened. The following Table gives the vertical heights for different pressures. Beyond 15 libs pressure a force pump is generally used instead of a vertical feed pipe, because the great length would not only be inconvenient, but liable to accident. When the steam is at this pressure it can be used expansively, that is, the valve can be shut at half a three quarter stroke, and the remainder of the stroke supplied by the expansion of the steam to common pressure; this is found a very economical mode of working an engine.

TABLE.

—Libs Pressure on the Square inch of the area of Safety Valve.	—Feet of Vertical Height of Feed Pipe measured from Water Line in Boiler.
5 libs	13 feet.
6 —	15 —
7 —	18 —
8 —	20 —
9 —	23 —
10 —	25 —
11 —	28 —
12 —	30 —
13 —	33 —
14 —	35 —
15 —	38 —

The following Table exhibits the expansive force of steam, expressing the degrees of heat at each lib of pressure on the safety valve.

Degrees of Heat.	Libs of Pressure.	Degrees of Heat.	Libs of Pressure.	Degrees of Heat.	Libs of Pressure.
212°	0	268°	24	298°	48
216	1	270	25	299	49
219	2	271	26	300	50
222	3	273	27	301	51
225	4	274	28	302	52
229	5	275	29	303	53
232	6	277	30	304	54
234	7	278	31	305	55
236	8	279	32	306	56
239	9	281	33	307	57
241	10	282	34	308	58
244	11	283	35	309	59
246	12	285	36	310	60
248	13	286	37	311	61
250	14	287	38	312	62
252	15	288	39	313	63
254	16	289	40	313½	64
256	17	290	41	314	65
258	18	291	42	315	66
260	19	293	43	316	67
261	20	294	44	317	68
263	21	295	45	318	69
265	22	296	46	319	70
267	23	297	47	320	71

By the following Rule the quantity of steam required to raise a given quantity of water to any given temperature is found.

RULE. Multiply the water to be warmed by the difference of temperature between the cold water and that to which it is to be raised, for a dividend; then to the temperature of the steam add 900 degrees, and from that sum take the required temperature of the water: this last remainder being made a divisor to the above dividend, the quotient will be the quantity of steam in the same terms as the water.

EXAMPLE.

What quantity of steam at 212° will raise 100 gallons of water at 60° up to 212°?

$$\frac{212° - 60° \times 100}{212° + 900° - 212} = 17 \text{ gallons of water formed into steam.}$$

Now, steam at the temperature of 212° is 1800 times its bulk in water; or 1 cubic foot of steam, when its elasticity is equal to 30 inches of mercury, contains 1 cubic inch of water.—Therefore 17 gallons of water converted into steam, occupies a space of 4090¾ cubic feet, having a pressure of 15 libs on the square inch.

In boiling by steam, using a jacket instead of blowing the steam into the water, I believe, about 10.5 square feet of surface are allowed for each horse capacity of boiler—*i. e.* a 14 horse boiler will boil water in a pan set in a jacket, exposing a surface of $10.5 \times 14 = 147$ square feet.

HORSE POWER.—Boulton and Watt suppose a horse able to raise 32,000 libs avoirdupois 1 foot high in a minute.

Desaguliers makes it 27,500 lbs.
Smeaton do. 22,916 do.

It is common in calculating the power of engines, to suppose a horse to draw 200 lbs at the rate of 2½ miles in an hour, or 220 feet per minute, with a continuance, drawing the weight over a pulley—now, $200 \times 220 = 44000$, *i. e.* 44000 lbs at 1 foot per minute, or 1 lb at 44000 feet per minute. In the following Table 32,000 is used.

One horse power is equal to raise —— gallons or —— lbs —— feet high per minute.

Feet High per min.	Ale Gallons.	Lbs Avoirdupois.	Feet High per min.	Ale Gallons.	Lbs Avoirdupois.
1	3123	32000	20	156	1600
2	1561½	16000	25	125	1280
3	1041	10666	30	104	1066
4	780	8000	35	89	914
5	624	6400	40	78	800
6	520	5333	45	69	711
7	446	4571	50	62	640
8	390	4000	55	56	582
9	347	3555	60	52	533
10	312	3200	65	48	492
11	284	2909	70	44	457
12	260	2666	75	41	426
13	240	2461	80	39	400
14	223	2286	85	37	376
15	208	2133	90	34	355
16	195	2000	95	32	337
17	183	1882	100	31	320
18	173	1777	110	28	291
19	164	1684	120	26	267

LENGTH OF STROKE.—The stroke of an engine is equal to one revolution of the crank shaft, therefore double the length of the cylinder. When stating the length of stroke, the length of cylinder is only given, that is, an engine with a 3 feet stroke, has its cylinder 3 feet long, besides an allowance for the piston.

The following Table shows the length of stroke, (or length of cylinder,) and the number of feet the piston travels in a minute, according to the number of strokes the engine makes when working at maximum.

When calculating the power of engines, the feet per minute are generally taken at 220.

Length of Stroke.	Number of Strokes.	Feet per minute.
Feet 2	43	172
— 3	32	192
— 4	25	200
— 5	21	210
— 6	19	228
— 7	17	238
— 8	15	240
— 9	14	250

CYLINDER. When an engine in good order is performing its regular work, the effective pressure may be taken at 8 libs on each square inch of the surface of the piston. In a former edition the maximum effective pressure was stated at 10 libs, but few engines are seldom or ever required to produce this work.

To calculate the power of an Engine.

RULE 1. Multiply the area of cylinder by the effective pressure = say 8 libs, the product is the weight the engine can raise. Multiply this weight by the number of feet the piston travels in one minute, which will give the momentum, or weight, the engine can lift 1 foot high per minute; divide this momentum by a horse power, as previously stated, and the quotient will be the number of horse power the engine is equal to.

RULE 2. 25 inches of the area of cylinder is equal to one horse power, the velocity of the engine being consequently 220 feet per minute.

EXAMPLE I.

What is the power of an engine, the cylinder being 42 inches diameter, and stroke 5 feet?

$$\frac{42^2 \times .7854 \times 10 \times 210}{44000} = 66.12 \text{ horse power.}$$

EXAMPLE II.

What size of cylinder will a 60 horse power engine require, when the stroke is 6 feet?

$$\frac{44000 \times 60}{228 \times 10} = 1158 \text{ inches, area of cylinder.}$$

Note. To find the power to lift a weight at any velocity, multiply the weight in libs by the velocity in feet, and divide by the horse power; the quotient will be the number of horse power required.

TABLE.

When the effective pressure on each inch of piston is	The area equal to one horse power will be
53 libs.	3.7 inches.
48 —	4.17 —
43 —	4.65 —
38 —	5.26 —
33 —	6.06 —
28 —	7.14 —
23 —	8.7 —
18 —	11.11 —
13 —	15.46 —
8 —	25. —

EXAMPLES *calculated by Rule 2d, and by the above Table.*

1st. What diameter is the cylinder of a 40 horse engine, common pressure?

$$\frac{\sqrt{40 \times 25}}{.7854} = 35.7, \text{ say } 35\tfrac{3}{4} \text{ inches diameter.}$$

2d. What diameter is the cylinder of a 40 horse engine, effective pressure 33 libs on the square inch?

$$\frac{\sqrt{40 \times 6.06}}{.7854} = 17.6, \text{ say } 17\tfrac{5}{8} \text{ inches diameter.}$$

3d. The cylinder of an engine is 40 inches diameter, and the effective pressure is 20 libs on the square inch.—What is the power of the engine?

Area of $40 = 1256.6 \div 10 = 125.6$ horse power.

STEAM WAYS.—The induction passages ought to be in area one twenty-fifth part of the area of cylinder.—Say, if area of cylinder be 25, the area of induction passage should be 1.—The eduction passage ought to be a little more in area than the induction, say one twenty-fourth part of the area of cylinder, in place of one twenty-fifth.

AIR PUMP.—The cubic contents of the air pump is equal to one-fourth of the cubic contents of cylinder, or when the air pump is half the length of the stroke of the engine, its area is equal to half the area of cylinder.

CONDENSER—is generally equal in capacity to the air pump; but when convenient it ought to be more: for when large, there is a greater space of vacuum, and the steam is sooner condensed.

COLD WATER PUMP.—The capacity of the cold water pump depends upon the temperature of the water. Many engines return their water, which cannot be so cold as water newly drawn from a river, well, &c.; but when water is at the common temperature, each horse power requires nearly $7\frac{1}{2}$ gallons per minute.* Taking this quantity as a standard, the size of the pump is easily found by the following Rule, viz.—Multiply the number of horse power by $7\frac{1}{2}$ gallons, and divide by the number of strokes per minute: this will give the quantity of water to be raised each stroke of pump. Multiply this quantity by 231, (the number of cubic inches in a gallon,) and divide by the length of effective stroke of pump, the quotient will be the area.

* An engine will work with a less supply of water, say 5 gallons per minute; but when water can be had without a considerable expense of power, $7\frac{1}{2}$ gallons is preferable; because an abundance of water keeps the condenser, &c. cool, and thereby produces a better vacuum.

EXAMPLE.

What diameter of pump is requisite for a 20 horse power steam engine, having a 3 feet stroke, the effective stroke of pump to be 15 inches?

$20 \times 7\frac{1}{2} = \frac{150}{32} = 4.6875$ gallons the pump lifts each stroke.

$\frac{4.6875 \times 231}{15} = 72.1875$ inches area of pump.

Hot Water Pump.—The quantity of water raised at each stroke ought to be equal in bulk to the 900th part of the capacity of the cylinder.

EXAMPLE I.

What quantity of feed water is necessary to supply the boiler of a 10 horse engine, common pressure?

$\frac{25 \times 10 \times 220}{144} = 382$ cubic feet of steam used, and the water contained in 1 cubic foot of steam is 1 cubic inch; so that 382 cubic inches of water, or $1\frac{1}{2}$ gallon, is required per minute; the pump, however, ought to be made sufficiently large to supply 2 gallons per minute, to make up for any leakage or waste of steam.

EXAMPLE II.

What quantity of feed water is necessary to supply the boiler of a 10 horse engine, the effective pressure 30 libs?

33 libs pressure = 6.06
28 libs pressure = 7.14
} 30 libs will be the medium = 6.6.

$\frac{6.6 \times 10 \times 220}{144} = 101$ cubic feet of steam equal to 101 cubic inches, or $\frac{4}{10}$ths nearly of a gallon of water. The pump ought to supply $\frac{3}{4}$ gallon per minute.

Proportions.—The length of stroke being 1, the length

of beam to centre will be 2, the length of crank .5, and the length of connecting rod 3.

The following Table shows the force which the connecting rod has to turn round the crank at different parts of the motion.

Col. A. Decimal proportions of descent of the piston, the whole descent being 1.

Col. B. Angle between the connecting rod and crank.

Col. C. Effective length of the lever upon which the connecting rod acts, the whole crank being 1.

Col. D. Decimal proportions of half a revolution of the fly-wheel.

Col. C. Also shows the force which is communicated to the fly-wheel, expressed in decimals, the force of the piston being 1.

A	B	C	D
.0	180°	.0	.0
.05	151½	.46	.128
.10	141	.62	.158
.15	131½	.74	.228
.2	123½	.830	.271
.25	117¼	.892	.308
.3	110¾	.94	.342
.35	104	.976	.377
.4	97½	.986	.41
.45	91¾	1.	.441
.5	85½	1.	.473
.55	80	.986	.507
.6	75	.956	.538
.65	69	.92	.572
.7	62½	.88	.607
.75	57½	.824	.642
.8	49	.746	.68
.85	42	.66	.723
.9	34	.546	.776
.95	23½	.390	.84
1.0	0	.000	1.0

FLY-WHEEL—is used to regulate the motion of the engine, and to bring the crank past its centres. The rule for finding its weight, is,—Multiply the number of horses' power of the engine by 2000, and divide by the square of the velocity of the circumference of the wheel per second, the quotient will be the weight in cwts.

EXAMPLE.

Required the weight of a fly wheel proper for an engine

of 20 horse power, 18 feet diameter, and making 22 revolutions per minute?

18 feet diameter = 56 feet circumference, × 22 revolutions per minute = 1232 feet, motion per minute ÷ 60 = $20\frac{1}{2}$ feet, motion per second; then $20\frac{1}{2}^2 = 420$ the divisor.

20 horse power × 2000 = 40000 dividend.

$$\frac{40000}{420\frac{1}{4}} = 90.4 \text{ cwt. weight of wheel.}$$

Parallel Motion. The radius and parallel bars are of the same dimensions; their length being generally one-fourth of the length of the beam between the two glands, or one-half the distance between the fulcrum and gland. Both pairs of straps are the same length between the centres, and which is generally three inches less than the half of the length of stroke

Governor, or Double Pendulum.—If the revolutions be the same, whatever be the length of the arms, the balls will revolve in the same plane, and the distance of that plane from the point of suspension, is equal to the length of a pendulum, the vibrations of which will be double the revolutions of the balls. For example; suppose the distance between the point of suspension and plane of revolution be 36 inches, the vibrations that a pendulum of 36 inches will make per minute, is $= \frac{375}{\sqrt{36}} = 62$ vibrations, and $\frac{62}{2} = 31$ revolutions per minute the balls ought to make.

For the sake of variety in the steam engine, we shall add the following table of the force and heat of steam. Also, the power of steam engines, and the method of computing it.

The force of Steam and the heat of it.

At the temperature of 212 degrees of Fahrenheit's Thermometer, the force of steam from water is just equal to the pressure of the atmosphere; but by increasing the heat, effects will be obtained, which are detailed in the following Table:

Steam predominating over the pressure of the atmosphere upon a safety valve, if its elastic force be equal to	Pounds per square inch requires to be maintained by a temperature equal to	Degrees of heat by Fahrenheit's Thermometer; and at these respective degrees of heat, steam can expand itself to about	Times its volume, and yet continue equal in its elasticity to the pressure of the atmosphere.
5	227½	5	
6	230¼	6	
7	232¾	7	
8	235¼	8	
9	237½	9	
10	239½	10	
15	250½	15	
20	259½	0	
25	267	25	
30	273	30	
35	278	35	
40	282	40	

By small additions to the temperature, an expansive force may be given to steam, so as to be equal to 400 times its natural bulk, or in any other proportion, provided the vessels, &c. that contain it be strong in proportion.

The Power of Steam Engines, and the Method of computing it.

In computing the power of a steam engine, THREE things must be duly observed.—1. The width or diameter of the piston or cylinder.—2. The length of the stroke. 3. The strength of the steam. It is supposed that the piston does, or ought to travel 220 feet per minute.

The power of an engine must vary according to the strength of the steam; and this must be the first point to be decided. This pressure is fixed at different ratios by different makers, varying from 7 to 12 lbs. upon the square inch. At Soho, they commonly fix it at 7 lbs. and Smeaton only reckoned 7 lbs. upon every *circular* inch.

Now the pressure being determined by the weight upon the safety valve, here is the most correct of all methods of ascertaining the power.

First. Find out how many hogsheads or pounds of water the engine is capable of raising ONE foot high in ONE minute.

Secondly. Divide that amount by the supposed ratios or supposed power of a horse to raise water 1 foot high in 1 minute of time, and the quotient will give horse powers of the engine.

RULE.—1. Find the area of the piston in square inches, by squaring the diameter and multiplying the amount by .7854, and the product will be the correct area. Or as the decimal .78 is near to .75 or $\frac{3}{4}$; for a ready calculation not *exactly* correct, square the diameter and take $\frac{3}{4}$ of that sum, and that will be the area, nearly; of the diameter of the piston multiplied by its circumference, and that divided by 4 will give its area in square inches.—2. The area of the piston in square inches must show the number of square inches exposed to the pressure of the steam; now if we multiply this area by the pressure upon every square inch, we shall have the whole pressure upon the piston, or the weight which the engine is capable of raising, and if the piston travel 220 feet per minute, that amount multiplied by 220 must give the weight of water that the engine is capable of lifting 1 foot high in one minute.—3. Messrs. Boulton and Watt suppose a horse able to raise 32000 lbs. avoirdupois, 1 foot in a minute. Dr. Desaguliers makes it 27500 lbs. Mr. Smeaton only 22916. Divide the number of lbs. that an engine of one horse power can raise 1 foot high in 1 minute, and the quotient will give the horse powers.

EXAMPLE.

What is the power of a steam engine, the cylinder of which is 24 inches, which makes 22 double strokes in a minute, each stroke being 5 feet long, and the force of the steam equal to 12 lbs. avoirdupois upon every square inch?

24 inches	452.4 square inches.
24	12 lbs. per square inch.
96	5428.8 the whole pressure upon the piston.
48	
576	
.7854	

452.3904 area, nearly 452.4 square inches.

The engine makes 22 *double* strokes, each 5 feet in a minute = 220 feet, then 5428.8 lbs. multiplied by
220 feet travelled per minute

will give 1194336 lbs. raised 1 foot high in 1 minute.

This divided by the standard of each engineer's calculation for a horse's power, and the quotients will give of

Boulton and Watt's	37	horse power.
Desagulier's	43	do. do.
Smeaton's	52	do. do.

WATER WHEEL.

Water. (*Hydrostatics.*)

Hydrostatics is the science which treats of the pressure, or weight, and equilibrium of water, and other fluids, especially those that are non-elastic.

Note 1. The pressure of water at any depth, is as its depth; for the pressure is as the weight, and the weight is as the height.

Note 2. The pressure of water on a surface any how immersed in it, either perpendicular, horizontal or oblique, is equal to the weight of a column of water, the base being equal to the surface pressed, and the altitude equal to the depth of the centre of gravity, of the *surface pressed*, below the top or surface of the fluid.

PROBLEM I.

In a vessel filled with water, the sides of which are upright and parallel to each other, having the top of the same dimensions as the bottom, the pressure exerted against the bottom, will be equal to the area of the bottom multiplied by the depth of water.

EXAMPLE.

A vessel 3 feet square and 7 feet deep, is filled with water; what pressure does the bottom support?

$$\frac{3^2 \times 7 \times 1000}{16} = 3937\tfrac{1}{2} \text{ libs avoirdupois.}$$

PROBLEM II.

A side of any vessel sustains a pressure equal to tne area of the side multiplied by half the depth, therefore the sides and bottom of a cubical vessel sustains a pressure equal to three times the weight of water in the vessel.

EXAMPLE I.

The gate of a sluice is 12 feet deep and 20 feet broad; what is the pressure of water against it?

$$\frac{20 \times 12 \times 6 \times 1000}{16} = 90000 = 40\tfrac{1}{5} \text{ tons nearly.}$$

From Note 2d.—The pressure exerted upon the side of a vessel, of whatever shape it may be, is as the area of the side and centre of gravity below the surface of water.

EXAMPLE II.

What pressure will a board sustain, placed diagonally through a vessel, the side of which is 9 feet deep, and bottom 12 feet by 9 feet?

$\sqrt{12^2 + 9^2} = 15$ feet, the length of diagonal board.

$$\frac{15 \times 9 \times 4\frac{1}{2} \times 1000}{16} = 37969 \text{ libs nearly.}$$

Though the diagonal board bisects the vessel, yet it sustains more than the half of the pressure in the bottom, for the area of bottom is 12×9, and the half of the pressure is half $60759 = 30375$.

The bottom of a conical or pyramidical vessel sustains a pressure equal to the area of the bottom and depth of water, consequently, the excess of pressure is three times the weight of water in the vessel.

Water. (*Hydraulics.*)

Hydraulics is that science which treats of fluids considered as in motion, it therefore embraces the phenomena exhibited by water issuing from orifices in reservoirs, projected obliquely, or perpendicularly, in *Jet-d'eaux*, moving in pipes, canals, and rivers, oscillating in waves, or opposing a resistance to the progress of solid bodies.

It would be needless here to go into the minutiæ of hydraulics, particularly when the theory and practice do not agree. It is only the general laws, deduced from experiment, that can be safely employed in the various operations of hydraulic architecture.

Mr. Banks, in his Treatise on Mills, after enumerating a number of experiments on the velocity of flowing water, by several philosophers, as well as his own, takes from thence the following simple rule, which is as near the truth as any that have been stated by other experimentalists.

Rule. Measure the depth (of a vessel, &c.) in feet, extract the square root of that depth, and multiply it by 5.4, which gives the velocity in feet per second; this multiplied by the area of the orifice in feet, gives the number of cubic feet which flows out in one second.

EXAMPLE.

Let a sluice be 10 feet below the surface of the water, its length 4 feet, and open 7 inches; required the quantity of water expended in one second?

$\sqrt{10} = 3.162 \times 5.4 = 17.0748$ feet velocity.

$\frac{4 \times 7}{12} = 2\frac{1}{3}$ feet $\times$ 17.0748 = 39.84 cubic feet of water per second.

If the area of the orifice is great compared with the head, take the medium depth, and two-thirds of the velocity from that depth, for the velocity.

Given the perpendicular depth of the orifice 2 feet, its horizontal length 4 feet, and its top 1 foot below the surface of water. To find the quantity discharged in one second:

The medium depth is $= 1.5 \times 5.4 = 8.10 - \frac{1}{3} = 5.40 \times 8 = 43.20$ cubic feet.*

The quantity of water discharged through slits, or notches, cut in the side of a vessel or dam, and open at the top, will be found by multiplying the velocity at the bottom by the depth, and taking $\frac{2}{3}$ of the product for the area; which again multiplied by the breadth of the slit, or notch, gives the quantity of cubic feet discharged in a given time.

EXAMPLE.

Let the depth be 5 inches, and the breadth 6 inches; required the quantity run out in 40 seconds?

The depth is .4166 of a foot.
The breadth is .5 of a foot.

$\sqrt{.4166} = .6455 \times 5.4 \times \frac{2}{3} = 2.3238 \times .4166 = 96825 \times .5 = .48412$ feet per second.

Then $.48412 \times 46. = 22.269$ cubic feet in 46 seconds.

There are two kinds of water wheels, undershot and overshot. Undershot when the water strikes the wheel at or below the centre. Overshot, when the water falls upon the wheel above the centre.

The effect produced by an *undershot* wheel, is from the impetus of the water. The effect produced by an *overshot* wheel, is from the gravity or weight of the water.

Of an undershot wheel the power is to the effect as 3 : 1. —Of an overshot wheel, the power is to the effect as 3 : 2— which is double the effect of an undershot wheel.

* The square root of the depth is not taken in this example, but when the depth is considerable, it ought to be taken.

The following is an Abridgment of SMEATON *on* WATER WHEELS.

UNDERSHOT.

Velocity of water in 1″ = V
Weight of 1 cub. in. of water = W
Area of sluice = A
Quantity of water = Q
Power of the water to produce mechanical effect = P

V. A. = Q in one second.
Q W. V = P; Power to produce mechanical effect.

POWER AND EFFECT OF MAXIMUM.

Velocity of wheel in 1″ = v
Effective velocity of water = E
Effect produced by the wheel = e
Weight raised = w
Velocity of weight raised = v

V = v = E
wv = e

P : e : : 10 : 3.62, or 3 : 1
V : v : : 10 : 3.5, or 5 : 2.

OVERSHOT.

Descent of water including head and diameter of wheel* = D
The weight of water expended in one second = W

D.W = P.

POWER AND EFFECT AT MAXIMUM.

Power of the water is = D.W = P
Effect of the wheel is = wv = e

P : e : : 10 : 6.6, or 3 : 2 nearly.
Double that of an undershot.

The velocity of maximum is = 3 feet in one second.

Since the effect of the overshot is double that of the undershot, it follows that the higher the wheel is in proportion to the whole descent, the greater will be the effect.

The maximum load for an overshot wheel, is that which reduces the circumference of the wheel to its proper velocity, = 3 feet in 1 second; and this will be known, by dividing the effect it ought to produce in a given time, by the space intended to be described by the circumference of the

* By Head is understood the distance between the orifice and the part of the wheel on which the water falls. The fall is the perpendicular height from the bottom of the wheel to the orifice.

wheel in the same time; the quotient will be the resistance overcome at the circumference of the wheel, and is equal to the load required, the friction and resistance of the machinery included.

The following is an extract from Banks on Mills, p. 152.

"The effect produced by a given stream in falling through a given space, if compared with a weight, will be directly as that space; but if we measure it by the velocity communicated to the wheel, it will be as the square root of the space descended through, agreeably to the laws of falling bodies.

"*Experiment* 1. A given stream is applied to a wheel at the centre; the revolutions per minute are 38.5

"*Ex.* 2. The same stream applied at the top, turns the same wheel 57 times in a minute.

"If in the first experiment the fall is called 1, in the second it will be 2: then $\sqrt{1} : \sqrt{2} :: 38.5 : 54.4$, which are in the same ratio as the square roots of the spaces fallen through, and near the observed velocity.

"In the following experiments a fly is connected with the water wheel.

"*Ex.* 3. The water is applied at the centre, the wheel revolves 13.03 times in one minute.

"*Ex.* 4. The water is applied at the vertex of the wheel, and it revolves 18.2 times per minute.

"As $13.03 : 18.2 :: \sqrt{1} : \sqrt{2}$ nearly.

"From the above we infer, that the circumferences of wheels of different sizes may move with velocities which are as the square roots of their diameters without disadvantage, compared one with another, the water in all being applied at the top of the wheel; for the velocity of falling water at the bottom or end of the fall is as the time, or as the square root of the space fallen through; for example, let the fall be 4 feet, then, As $\sqrt{16} : 1'' :: \sqrt{4} : \frac{1}{2}''$, the time of falling through 4 feet:—Again, let the fall be 9 feet, then, $\sqrt{16} : 1'' :: \sqrt{9} : \frac{3}{4}''$, and so for any other space, as in the following Table, where it appears that water will fall through one foot in a quarter of a second, through 4 feet in half a second, through 9 feet in 3 quarters of a second, and through 16 feet in one second. And if a wheel 4 feet in diameter

moved as fast as the water, it could not revolve in less than 1.5 second, neither could a wheel of 16 feet diameter revolve in less than three seconds; but though it is impossible for a wheel to move as fast as the stream which turns it, yet, if their velocities bear the same ratio to the time of the fall through their diameters, the wheel 16 feet in diameter may move twice as fast as the wheel 4 feet diameter."

TABLE.

Height of the fall in feet.	Time of falling in seconds.	Height of the fall in feet.	Time of falling in seconds.
1	.25	14	.935
2	.352	16	1.
3	.432	20	1.117
4	.5	24	1.22
5	.557	25	1.25
6	.612	30	1.37
7	.666	36	1.5
8	.706	40	1.58
9	.75	45	1.67
10	.79	50	1.76
12	.864		

POWER AND EFFECT.—The power water has to produce mechanical effect, is as the quantity and fall of perpendicular height.—The mechanical effect of a wheel is as the quantity of water in the buckets and the velocity.

The power is to the effect as 3 : 2, that is, suppose the power to be 9000, the effect will be $= \frac{9000 \times 2}{3} = \frac{18000}{3}$ $= 6000$.

HEIGHT OF THE WHEEL.—The higher the wheel is in proportion to the fall, the greater will be the effect, because it depends less upon the impulse, and more upon the gravity of the water; however, the head should be such, that the water will have a greater velocity than the circumference of the wheel: and the velocity that the circumference

ot the wheel ought to have, being known, the head required to give the water its proper velocity, can easily be known from the rules of Hydrostatics.

VELOCITY OF THE WHEEL.—Banks, in the foregoing quotation, says, "That the circumferences of overshot wheels of different sizes may move with velocities as the square roots of their diameters, without disadvantage."—Smeaton says, "Experience confirms that the velocity of 3 feet per second is applicable to the highest overshot wheels, as well as the lowest; though high wheels may deviate further from this rule, before they will lose their power, by a given aliquot part of the whole, than low ones can be admitted to do; for a 24 feet wheel may move at the rate of 6 feet per second, without losing any considerable part of its power."

It is evident that the velocities of wheels, will be in proportion to the quantity of water and the resistance to be overcome:—if the water flows slowly upon the wheel, more time is required to fill the buckets than if the water flowed rapidly; and whether Smeaton or Banks is taken as a data, the mill-wright can easily calculate the size of his wheel, when the velocity and quantity of water in a given time is known.

EXAMPLE I.

What power is a stream of water equal to, of the following dimensions, viz. 12 inches deep, 22 inches broad; velocity 70 feet in $11\frac{3}{4}$ seconds, and fall 60 feet?—Also, what size of a wheel could be applied to this fall?

$\frac{12 \times 22}{144} = 1.83$ square feet:—area of stream.

$11\frac{3}{4}'' : 70 : : 60'' : 357.5$ lineal feet per min.—velocity.

$357.5 \times 1.83 = 654.225$ cubic feet per minute.

$654.225 \times 62.5 = 40889.0625$ avoir. libs per minute.

$40889.0625 \times 60 = 2453343.7500$ momentum at a fall of 60 feet.

$\frac{2453343.7500}{44000} = 55.7$ horse power.

3 : 2 : : 55.7 : 37.13 effective power.

The diameter of a wheel applicable to this fall, will be 58 feet, allowing one foot below for the water to escape, and one foot above for its free admission.

$58 \times 3.1416 = 182.2128$ circumference of wheel.

$60 \times 6 = 360$ feet per minute, = velocity of wheel.

$\frac{654.225}{360} = 1.8$ sectional area of buckets.

The buckets must only be half full, therefore $1.8 \times 2 = 3.6$ will be the area.

To give sufficient room for the water to fill the buckets, the wheel requires to be four feet broad, now $\frac{3.6}{4} = .9$, say 1 foot depth of shrouding.

$\frac{360}{182.2128} = 1.9$ revolutions per minute the wheel will make.

	Power of water	= 55.7 H. P.	
	Effective power of do.	= 37.13 H. P.	
Dimensions of wheel.	Diameter	= 58 feet.	*Ans.*
	Breadth	= 4 feet.	
	Depth of shrouding	= 1 foot.	

EXAMPLE II.

What is the power of a water wheel, 16 feet diameter, 12 feet wide, and shrouding 15 inches deep?

$16 \times 3.1416 = 50.2656$ circumference of wheel.

$12 \times 1\frac{1}{4} = 15$ square feet, sectional area of buckets.

$60 \times 4 = 240$ lineal feet per minute, = velocity.

$240 \times 15 = 3600$ cubic feet water, when buckets are full; when half full, 1800 cubic feet.

$1800 \times 62.5 = 112500$ avoir. libs of water per minute.

$112500 \times 16 = 1800000$ momentum falling 16 feet.

$3 : 2 :: 1800000 : \frac{1200000}{44000} = 27$ horse power.

BUCKETS.—The number of buckets to a wheel should be as few as possible, to retain the greatest quantity of water; and their mouths only such a width as to admit the requisite

quantity of water, and at the same time sufficient room to allow the air to escape.

THE COMMUNICATION OF POWER.—There are no prime movers of machinery from which power is taken in a greater variety of forms than the water wheel, and among such a number there cannot fail to be many bad applications.

Suffice it here to mention one of the worst, and most generally adopted. For driving a cotton mill in this neighbourhood, there is a water wheel about 12 feet broad, and 20 feet diameter; there is a division in the middle of the buckets upon which the segments are bolted round the wheel, and the power is taken from the vertex: from this erroneous application, a great part of the power is lost; for the weight of water upon the wheel presses against the axle in proportion to the resistance it has to overcome, and if the axle was not a large mass of wood, with very strong iron journals, it could not stand the great strain which is upon it.

The most advantageous part of the wheel, from which the power can be taken, is that point in the circle of gyration horizontal to the centre of the axle; because, taking the power from this part, the whole weight of water in the buckets acts upon the teeth of the wheels; and the axle of the water wheel suffers no strain.

The proper connexion of machinery to water wheels is of the first importance, and mismanagement in this particular point is often the cause of the journals and axles giving way, besides a considerable loss of power.

To find the radius of the circle of gyration in a water wheel is therefore of advantage to the saving of power, and the following example will show the rule by which it is found.—*See Centre of Gyration.*

EXAMPLE.

Required the radius of the circle of gyration in a water wheel, 30 feet diameter; the weight of the arms being 12 tons, shrouding 20 tons, and water 15 tons.

30 feet diameter, radius = 15 feet.

$$\left.\begin{array}{ll} S & 20 \times 15^2 = 4500 \times 2 = 9000 \\ A & \dfrac{12 \times 15^2}{3} = 900 \times 2 = 1800 \end{array}\right\}$$ The opposite side of the water wheel must be taken.

$$\begin{array}{lll} W & 15 \times 15^2 = 3375 & = 3375 \\ \hline & 2 \times 20 + 12 = 64 & \\ & W \quad 15 & \dfrac{14175}{79} = 179, \text{ the square root.} \\ & \quad 79 & \end{array}$$

of which is $13\frac{4}{10}$ feet, the radius of the circle of gyration.

PUMPS.

There are two kinds of pumps, lifting and forcing. The lifting, or common pumps, are applied to wells, &c., where the depth does not exceed 32 feet; for beyond this depth they cannot act, because the height that water is forced up into a vacuum, by the pressure of the atmosphere, is about 34 feet.

The force pumps are those that are used on all other occasions, and can raise water to any required height.—Bramah's celebrated pump is one of this description, and shows the amazing power that can be produced by such application, and which arises from the fluid and non-compressible qualities of water.

The power required to raise water any height is equal to the quantity of water discharged in a given time, and the perpendicular height.

EXAMPLE.

Required the power necessary to discharge 175 ale gallons of water per minute, from a pipe 252 feet high?

One ale gallon of water weighs $10\frac{1}{4}$ libs avoir. nearly.

$$175 \times 10\tfrac{1}{4} = 1799 \times 252 = \frac{453348}{44000} = 10.3 \text{ horse power}$$

The following is a very simple Rule, and easily kept in remembrance.

Square the diameter of the pipe in inches, and the product will be the number of libs of water avoirdupois contained in every yard length of the pipe. If the last figure of the product be cut off, or considered a decimal, the remaining figures will give the number of ale gallons in each yard of pipe; and if the product contains only one figure, it will be tenths of an ale gallon. The number of ale gallons multiplied by 282, gives the cubic inches in each yard of pipe, and the contents of a pipe may be found by Proportion.

EXAMPLE.

What quantity of water will be discharged from a pipe 5 inches diameter, 252 feet perpendicular height, the water flowing at the rate of 210 feet per minute?

$5^2 \times \frac{210}{3} = 175$ ale gallons per minute.

$5^2 \times \frac{252}{3} = 2100$ libs water in pipe.

$\frac{2100 \times 210}{44000} = 10$ horse power required to pump that quantity of water.

The following Table gives the contents of a pipe one inch diameter, in weight and measure, which serves as a standard for pipes of other diameters, their contents being found by the following rule.

Multiply the numbers in the following Table against any height, by the square of the diameter of the pipe, and the product will be the number of cubic inches avoirdupois ounces, and wine gallons of water, that the given pipe will contain.

EXAMPLE.

How many wine gallons of water is contained in a pipe 6 inches diameter, and 60 feet long?

$2.4480 \times 36 = 88.1280$ wine gallons.

In a wine gallon there are 231 cubic inches.

TABLE.

ONE INCH DIAMETER.			
Feet high.	Quantity in cubic inches.	Weight in avoir. oz.	Gallons wine measure.
1	9.42	5.46	.0407
2	18.85	10.92	.0816
3	28.27	16.38	.1224
4	37.70	21.85	.1632
5	47.12	27.31	.2040
6	56.55	32.77	.2448
7	65.97	38.23	.2423
8	75.40	43.69	.3264
9	84.82	49.16	.3671
10	94.25	54.62	.4080
20	188.49	109.24	.8160
30	282.74	163.86	1.2240
40	376.99	218.47	1.6300
50	471.24	273.09	2.0400
60	565.49	327.71	2.4480
70	659.73	382.33	2.8560
80	753.98	436.95	3.2640
90	848.23	491.57	3.6700
100	942.48	546.19	4.0800
200	1884.96	1092.38	8.1600

The resistance arising from the friction of water flowing through pipes, &c. is directly as the velocity of the water, and inversely as the circumference of the pipe.

The data given is a medium, and which is 1-5th of the whole resistance; this is the standard generally adopted, being considered as most correct.

EXAMPLE I.

What is the power requisite to overcome the resistance and friction of a column of water 4 inches diameter, 100 feet high, and flowing at the velocity of 300 feet per minute?

$$\frac{546.19 \times 4^2}{16} = 546.19, \text{ say } 546.2.$$

$$\frac{546.2 \times 300}{44000} = 3.7 \text{ } \tfrac{1}{5}\text{th of which is } .7, \text{ therefore the}$$

power required to overcome the resistance occasioned by the weight and friction of the water will be $3.7 + .7 = 4.4$ H. P., say 4.5 horse power.

EXAMPLE II.

There is a cistern 20 feet square, and 10 feet deep, placed on the top of a tower 60 feet high; what power is requisite to fill this cistern in 30 minutes, and what will be the diameter of the pump, when the length of stroke is 2 feet, and making 40 per minute?

$20 \times 20 \times 10 = 4000$ cubic contents of cistern.

$$\frac{4000}{30} = 133.3 \text{ cubic feet of water per minute.}$$

$$\frac{133.3 \times 1000}{16} = 8331.25 \text{ libs avoir. per minute.}$$

$$\frac{8331.25 \times 60}{44000} = 11.36 \text{ horse power, } 1.5\text{th of which is}$$

$= 2.27 + 11.11 = 13.63$ horse power required.

$$2 \times 40 = 80 \qquad \frac{133.3}{80} = 1.7 \times 144 = \frac{244.80}{.7854} = 311.7, \text{ now}$$

$\sqrt{311.7} = 17.6$ inches diameter of pump required.

Founders generally prove the pipes they cast to stand a certain pressure, which is calculated by the weight of a perpendicular column of water, the area being equal to the area of the pipe, and the height equal to any given height.

To ascertain the exact pressure of water to which a pipe is subjected, a safety valve is used, generally of 1 inch diameter, and loaded with a weight equal to the pressure required: for example, a pipe requires to stand a pressure of 300 feet, what weight will be required to load the safety valve 1 inch diameter?

Feet. Inches. Ounces.

$$300 \times 12 = 3600 \times .7854 = \frac{2827.4400 \times 1000}{1728} = \frac{1636\frac{1}{4}}{16}$$

$= 102$ libs $4\frac{1}{4}$ oz. weight required.

Each of the weights for the safety valves of these Hydrostatic proving machines are generally made equal to a pressure of a column of water 50 feet high, the area being the area of the valve.

50 feet of pressure on a valve 1 inch diam. = 17.06 libs.
50 do. do. do. $1\frac{1}{4}$ do. = 26.65 do.
50 do. do. do. $1\frac{1}{2}$ do. = 38.38 do.
50 do. do. do. 2 do. = 68.24 do.

In pumping, there is always a deficiency owing to the escape of water through the valves; to account for this loss, there is an allowance of 3 inches for each stroke of piston rod: for example, a 3 feet stroke may be calculated at 2 feet 9 inches.

There is a town, the inhabitants of which amount to 12000, and it is proposed to supply it with water, from a river running through the low grounds 250 perpendicular feet below the best situation from the reservoir.

It is required to know the power of an engine capable of lifting a sufficient quantity of water, the daily supply being calculated at 10 ale gallons to each individual; also, what size of pump and pipes are requisite for such?

$$12000 \times 10 = 120000 \text{ gallons per day.}$$

Engine is to work 12 hours, $\frac{120000}{12} = 10000$ gallons per hour.

$$\frac{10000}{60} = 166.6 \text{ gallons per minute.}$$

The pump to have an effective stroke of $3\frac{3}{4}$ feet, and making 30 strokes per minute.

$$\frac{166.6}{30} = 5.5533 \text{ gallons each stroke.}$$

$282 \times 5.6 = 1579.2$ cubic inches of water each stroke.

3 feet 9 in. $= 45$ in. $\frac{1579.2}{45} = 35.1$ inches, area of pump.

$\frac{35.1}{7854} = 44.7$, therefore $\sqrt{44.7} = 6.7$ diam. of pump.

The pipes will require to be at least the diameter of the pump; if they are a little more, the water will not require to flow so quickly through them, and thereby cause less friction.

The power of the engine will be

166.6 gal. × 10¼ lb. × 250 feet = 426925 momentum

$\frac{426925}{44000}$ = 9.7, add 1-5th = 11.64 horse power.

$\frac{426925}{32000}$ = 13.3, —— = 15.96 do. *Watt.*

$\frac{426925}{27500}$ = 15.5, —— = 18.6 do. *Desaguliers*

$\frac{426925}{22916}$ = 18.6 —— = 22.32 do. *Smeaton.*

This table is inserted from Ferguson's Mechanical Lectures. The speed is calculated for a millstone six feet diameter; but as millstones in general use are seldom more than four feet six inches diameter, the speed must be increased accordingly; and it is found by experience, that millstones of this size will work well when making 120 revolutions per minute. Such a mill as this, with a water wheel 18 feet diameter, and a fall of water about 7½ feet, will require about 32 hogsheads every minute to turn the wheel with the third part of the velocity with which the water falls, and to overcome the resistance arising from the friction of gears and attrition of the stones in grinding the corn.

Height of the fall of water.	Velocity of the water per second.	Velocity of the wheel per second.	Revolutions of the wheel per minute.	Revolutions of the millstone for one of the wheels.	Cogs in the wheel and staves in the trundle.		Revolutions of the millstone per minute.
Feet.	Feet and hundredth parts of a foot.	Feet and hundredth parts of a foot.	Revolutions and hundredth parts of a revolution.	Revolutions and hundredth parts of a revolution.	Cogs.	Staves.	Revolutions and hundredth parts of a revolution.
1	8.02	2.67	2.83	21.20	127	6	59.92
2	11.34	3.78	4.00	15.00	105	7	60.00
3	13.89	4.63	4.91	12.22	98	8	60.14
4	16.04	5.35	5.67	10.58	95	9	59.87
5	17.93	5.98	6.34	9.46	85	9	59.84
6	19.64	6.55	6.94	8.64	78	9	60.10
7	21.21	7.07	7.50	8.00	72	9	60.00
8	22.68	7.56	8.02	7.48	71	9	59.67
9	24.05	8.02	8.51	7.05	70	10	59.57
10	25.35	8.45	8.97	6.69	67	10	60.09
11	26.59	8.86	9.40	6.38	64	10	60.16
12	28.77	9.26	9.82	6.11	61	10	59.90
13	28.91	9.64	10.22	5.87	59	10	60.18
14	30.00	10.00	10.60	5.66	56	10	59.36
15	31.05	10.35	10.99	5.46	55	10	60.48
16	32.07	10.69	11.34	5.29	53	10	60.10
17	33.06	11.02	11.70	5.13	51	10	59.67
18	34.02	11.34	12.02	4.99	50	10	60.10
19	34.95	11.65	12.37	4.85	48	10	60.61
20	35.86	11.95	12.68	4.73	47	10	59.59
1	2	3	4	5	6		7

TABLE *showing the Relative Power of Overshot Wheels, Steam Engines, Horses, Men, and Windmills of different kinds, by Fenwick.*

Number of ale gallons delivered on overshot wheel 10 feet in diameter, every minute.	Diameter of the cylinder in the common steam engine, in inches.	Diameter of the cylinder in the improved steam engine, in inches.	Number of horses, working 12 hours per day, and moving at the rate of two miles per hour.	Number of men, working 12 hours a day.	Radius of Dutch sails in their common position, in feet.	Radius of Dutch sails in their best position, in feet.	Radius of Mr. Smeaton's enlarged sails, in feet.	Height to which these different powers will raise 1000 lbs. avoirdupois in a minute.
230	8.	6.12	1	5	21.24	17.89	15.65	13
390	9.5	7.8	2	10	30.04	25.20	22.13	26
528	10.5	8.2	3	15	36.80	30.98	27.11	39
660	11.5	8.8	4	20	42.48	35.78	31.30	52
720	12.5	9.3	5	25	47.50	40.00	35.00	65
970	14.	10.55	6	30	52.03	43.82	38.34	78
1170	15.4	11.75	7	35	56.90	47.33	41.44	90
1350	16.8	12.8	8	40	60.09	50.60	44 27	104
1455	17.3	13.6	9	45	63.73	53.66	46.96	117
1584	18.5	14.2	10	50	67.17	56.57	49.50	130
1740	19.4	14.8	11	55	70.46	59.33	51.91	143
1900	20.2	15.2	12	60	73.59	61.97	54.22	156
2100	21.	16.2	13	65	76.59	64.5	56.43	169
2300	22.	17.	14	70	79.49	66.94	58.57	182
2500	23.1	17.8	15	75	82.27	69.28	60.62	195
2680	23.9	18.3	16	80	84.97	71.55	62.61	208
2870	24.7	19.	17	85	87.07	73.32	64.16	221
3055	25.5	19.6	18	90	90.13	75.90	67.41	234
3240	26.2	20.1	19	95	92.60	77.98	68.23	247
3420	27.	20.7	20	100	95.00	80.00	70.00	260
3750	28.5	22.2	22	110	99.64	83.90	73.42	286
4000	29.8	23.	24	120	104.06	87.63	76.68	312
4460	31.1	23.9	26	130	108.32	91.22	79.81	388
4850	32.4	24.7	28	140	112.20	94.66	82.82	364
5250	33.6	25.5	30	150	116.35	97.98	85.73	396

ON THE STRENGTH OF MATERIALS.

The strength of materials is a subject of great importance in mechanics, and one which, of all the branches of this useful science, is the least understood. Several very eminent mathematicians have exercised their talents and ingenuity in forming theories for estimating the strength of beams according to the various positions in which they are, but unfortunately, they made no experiments; therefore, they had no better foundation than mere hypothesis; consequently are totally at variance with practice.

It is not intended, however, in this short abstract, to perplex the reader with theory, but to furnish the artisan with a few properties, which to him will be more useful than many discordant suppositions.

A body may be exposed to four different kinds of strains. 1st. It may be torn asunder by some force applied in the direction of its length, as in the case of ropes, &c. 2d. It may also be crushed by a force applied in the direction of its length, as in the case of pillars, posts, &c. 3d. It may be broken across by a force acting perpendicularly to its length, as in joints, levers, &c. 4th. It may be wrenched or twisted by a force acting in a kind of circular direction at the extremity of a lever, as in the case of wheel-axles, &c.

The first of these, viz. the direct cohesion of bodies, is one which seldom comes under the consideration of the mechanic or engineer; and if any former experiments can be obtained, they are generally sufficient for his purpose; or no reason can be assigned why the strength should not vary directly as the section of fracture, and is totally independent of the length in position, except so far as the weight of the body may increase the force applied. Neglecting this, and supposing the body uniform in all its parts, *the strength of bodies exposed to strains in the direction of their length, is directly proportionate to their transverse area, whatever may be their figure, length, or position.*

Experiments on the direct cohesion of all bodies are attended with great difficulty, in consequence of the enormous force required to produce a separation of the parts, in bars of any considerable dimensions.

Some experiments of this kind, however, have been made, the results of which are as follow, all reduced to the section of a square inch.

		lbs.
Gold Cast,		20,000 to 24,000
Silver Cast,		40,000 to 43,000
Copper Cast,	Japan,	19,500
	Barbary,	22,000
	Hungary,	31,000
	Anglesea,	34,000
	Sweden,	37,000
Iron Cast,		42,000 to 59,000
Iron Bar,	Ordinary,	65,000
	Stirian,	78,000
	Best Swedish & Russian,	84,000
	Horse Nails,	71,000
Steel Bar,	Soft,	120,000
	Razor tempered,	150,000
Tin Cast,	Malacca,	3,100
	Banca,	3,600
	Block,	3,800
	English Block,	5,200
	English Grain,	6,500
Lead Cast,		860
Regulus of Antimony,		1,000
Zinc,		2,600
Bismuth,		2,900

It is very remarkable that almost all mixtures of metals are stronger or more tenacious than the metals themselves, much depending upon the proportion of the ingredients; and these proportions are different in metals.

Oak,		9,000
Ash,		17,000
Pine,	from 10,000 to	13,000

On the Resistance of Bodies when pressed longitudinally.

It is obvious that a body when pressed endwise, by a sufficient force, may be crushed and destroyed, either by a total separation of the matter by which it is composed, or by bending it, whereby it is broke across: if the length of the body be very inconsiderable the former is the almost certain result; but if its length be much more than its breadth and thickness, it generally bends before breaking.

Although many experiments, and some very intricate analytical investigations have been made upon this subject, yet little can be advanced that will be of use to the practical engineer. It may be observed, that a pillar of hard stone of Giory, whose section is a square foot, will bear with perfect safety 664,000 lbs.; and its extreme strength is 871,000 lbs.

Good brick will carry with safety 320,000 lbs. on a square foot; and chalk, 9,000 lbs.

It requires a power of 400,000 lbs. to crush a cube of one-quarter of an inch of cast iron.

The most usual strain, and therefore the one with which it is most important for us to be well informed is, that by which a body is broken across, from the force of weight acting perpendicularly or obliquely to its length, while the beam itself is supported by its two extremities, or by one end fixed into a wall, or otherwise.

From various experiments which have been made, the following results have been deduced:

1. The lateral strength of beams are inversely as their lengths.

2. The lateral strengths of the beams are directly as their breadth.

3. The lateral strength of beams are as the square of their depth.

4. In square beams the lateral strengths are as the cube of one side.

5. In round beams as the cube of the diameter.

6. The lateral strength of a beam with its narrow face upwards, is to its strength with the broad face upwards as

the breadth of the broader face to the breadth of the narrower.

7. The strength of beam *supported only* at its extremes, is to the strength of the same when *fixed* at both ends, as 1 to 2.

8. The strength of a beam with the weight or load suspended from the centre is to the strength when the load is equally divided in the length of the beam, as 1 to 2.

According to the experiments made by Mr. Banks, the worst or weakest piece of oak he tried bore 600 pounds, though much bended, and 2 pounds more broke it. The strongest piece broke with 974 pounds.

The worst piece of Deal bore 460 pounds, but broke with 4 more. The best piece bore 690 pounds, but broke with a little more.

The weakest cast iron bar bore 2190 pounds, and strongest 2980 pounds.

Also, these experiments were made upon pieces 1 inch square, the props exactly 1 foot asunder, and the weight suspended from the centre, the ends lying loose.

By way of illustration we will add a few examples for the exercise of the Reader.

What weight suspended from the middle of an oak beam, whose length is 10 feet, and each side of its square end 4 inches; will break it when supported at each end?

By article 1st, the lateral strengths of beams aro inversely as the lengths, and (article 4) as the cube of one side.

Then, as a piece 1 foot long and 1 inch square bore 660 pounds, one 10 feet long would bear 66 lbs., and 66 multiplied by 64, the cube of 4 = 4224 pounds the weight, the above beam would support. If the ends of the beam were prevented from rising it would bear 8448 pounds; and if the weight was equally diffused in its length, it would support 16896 pounds.

Required the strength of a hollow shaft of cast iron supported at its two extremes, 5 inches diameter, the diameter of the hollow being 4 inches, and the length of the shaft 10 feet?

First find the strength of a solid shaft 5 inches diameter, and then that of one 4 inches, which deduced from the former, gives its strength.

The strength of round beams are as the cubes of their diameter, and the cube of 5 is 125; this multiplied by 170, the strength of a round bar 1 inch diameter and 10 feet long, gives 21,375 pounds for the strength of a solid shaft 5 inches diameter and 10 feet long.

The cube of 4 is 64 multiplied by 171, equals 10,944 pounds, the strength of a solid shaft 3 inches diameter and 10 feet long. Now 21,375 — 10,944 = 10,431 pounds, the strength of the hollow shaft required.

N. B. The diameter of a solid having the *same quantity of matter* with the tube is 3, but the strength of it would not be *half* that of the ring. Engineers have of late introduced this improvement into their machines, the axles of cast iron being made hollow, when the size and other circumstances will admit of it.

Required the strength of a piece of deal 6 inches broad, 2 inches deep, and 5 feet long, placed edgeways, and the weight suspended from the centre?

Answer, 6624 pounds.

What weight will a cast iron beam bear supported in the centre, the length of the beam being 6 feet 8 inches deep, and 1 inch thick?

Answer, 10 tons, 8 cwt. 2 quarters, and 8 lbs.

If a plank be three inches thick, and 12 inches broad, how much more will it bear with its edge than with its flat side uppermost?

Answer, 4 times more with its edge uppermost.

With respect to the fourth strain: viz. the twist to which bars or shafts in an upright position are liable by the wheel which drives them, and the resistances they have to overcome, little that will be satisfactory can be advanced. Mr. Banks observes, that a cast iron bar an inch square, and fixed at the one end, and 631 pounds suspended by a wheel of 2 feet diameter, fixed on the other end, will break by the

twist: though some have required more than 1000 pounds in similar situations to break them by the twist.

The strength to resist the twisting strain is as the cube of like lateral dimensions.

In concluding these plain statements it may be necessary to remind our readers, that in applying these rules to practical purposes, care should be taken to make the beams, &c. sufficiently strong: if they are but just able to support the stress they will be in danger of breaking. In most cases the strength should be 2 or 3 times the stress, and where the stress may be in equal, or the pressure exerted in a variable manner, by jerks, &c. the strength should be considerably more than that.

In all the preceding examples the beams are supposed only just able to support the load.

The following are the results of experiments made by Mr. Emerson, which state the load that may be safely borne by a square inch rod of each.

	Pounds avoirdupois
*Iron rod, an inch square, will bear,	76,400
Brass,	35,600
Hempen rope,	19,600
Ivory,	15,700
Oak, box, yew, plumtree,	7,850
Elm, ash, beech,	6,070
Walnut, plum,	5,360
Red pine, holly, elder, plane, crab,	5,000
Cherry, hazel,	4,760
Alder, asp, birch, willow,	4,290
Lead	430
Free stone,	914

Mr. Barlow's opinion of this table is, "We shall only observe here, that they all fall very short of the ultimate strength of the woods to which they refer."

Mr. Emerson also gives the following practical rule, viz.

* Tenacity of copper compared with iron is 5: 9 nearly, or 1: 1.8, i. e. copper being 1, iron is 1.8.

"that a cylinder, whose diameter is d inches, loaded to one-fourth of its absolute strength, will carry as follows :

	cwt.
Iron,	$135 \times d^2$
Good rope,	$22 \times d^2$
Oak,	$14 \times d^2$
Pine,	$9 \times d^2$

Captain S. Brown made an experiment on Welsh pig iron, and the result is described as follows :

"A bar of cast iron, Welsh pig, $1\frac{1}{4}$ inch square, 3 feet 6 inches long, required a strain of 11 tons 7 cwt. (25,424 libs,) to tear it asunder, broke exactly transverse, without being reduced in any part ; quite cold when broken, particles fine, dark bluish grey colour."—From this experiment, it appears that 16,265 libs will tear asunder a square inch of cast iron.

Mr. G. Rennie also made some experiments on cast iron, and the result was, "that a bar one inch square, cast horizontal, will support a weight of 18,656 libs—and one cast vertical, will support a weight of 19,488 libs."

There have been several experiments made on mallea ble iron, of various qualities, by different engineers.

The mean of Mr. Telford's experiments, is $29\frac{1}{4}$ tons.
The mean of Capt. S. Brown's do. is 25 do.

and the mean between these two means, is 27 tons, nearly ; which may be assumed as the medium strength of a malleable iron bar 1 inch square.

From a mean, derived by experiments, performed by Mr. Barlow, it appears that the strength of direct cohesion, on a square inch of

		libs.
Box	is about	20,000
Ash	—	17,000
Teak	—	15,000
Pine	—	12,000

Beech	—	—	11,500
Oak	—	—	10,000
Pear	—	—	9,800
Mahogany	—	—	8,000

Each of these weights may be taken as a correct data for the cohesive strength of the wood to which they belong, but this is the absolute and ultimate strength of the fibres; and therefore, if the quantity that may be safely borne be required, not more than two-thirds of the above values must be used.

TABLE

Of Sizes and Strength of Chains.

Size of chains.	Will carry	Weight of chains per fathom.
$\frac{1}{2}$ inch	3 tons	14 lb.
$\frac{9}{16}$ —	$4\frac{1}{2}$ —	18 —
$\frac{5}{8}$ —	6 —	24 —
$\frac{11}{16}$ —	$7\frac{1}{2}$ —	28 —
$\frac{3}{4}$ —	9 —	32 —
$\frac{13}{16}$ —	11 —	38 —
$\frac{7}{8}$ —	13 —	44 —
$\frac{15}{16}$ —	15 —	50 —
1 —	17 —	56 —
$1\frac{1}{16}$ —	19 —	62 —
$1\frac{1}{8}$ —	$21\frac{1}{2}$ —	70 —
$1\frac{3}{16}$ —	24 —	78 —
$1\frac{1}{4}$ —	27 —	86 —
$1\frac{5}{16}$ —	30 —	96 —
$1\frac{3}{8}$ —	33 —	108 —
$1\frac{7}{16}$ —	36 —	115 —
$1\frac{1}{2}$ —	40 —	125 —

A Table of Specific Gravities of Bodies.

Platina (pure)	23000	Tin	7320
Fine gold	19400	Clear crystal glass	3150
Standard gold	17724	Granite	3000
Quicksilver (pure)	14000	Marble and hard stone	2700
Do. (common)	13600	Common green glass	2600
Lead	11325	Flint	2570
Fine silver	11091	Common stone	2520
Standard silver	10535	Clay	2160
Copper	9000	Brick	2000
Copper halfpence	8915	Common earth	1984
Gun metal	8784	Nitre	1900
Cast brass	8000	Ivory	1825
Steel	7850	Brimstone	1810
Iron	7645	Solid gunpowder	1745
Cast iron	7425	Sand	1520
Coal	1250	Ash	800
Boxwood	1030	Maple	755
Sea water	1030	Elm	600
Common water	1000	Pine	550
Oak	925	Charcoal	400
Gunpowder close shaken	937	Cork	240
Gunpowder in a loose heap	836	Air at a mean state	$1\frac{2}{9}$

Note. The several sorts of wood are supposed to be dry. Also, as a cubic foot of water weighs just 1000 ounces avoirdupois, the numbers in this Table express, not only the specific gravities of the several bodies, but also the weight of a cubic foot of each in avoirdupois ounces; and therefore, by proportion, the weight of any other quantity, or the quantity of any other weight, may be known. Also, 100 cubic inches of common air weigh nearly $31\frac{1}{2}$ grains troy, or $1\frac{1}{7}$ drams avoirdupois.

TABLES OF THE WEIGHT OF MALLEABLE AND CAST IRON PLATES, BARS, &c.

TABLE *of the Weight of a Square Foot of Cast and Malleable Iron, Copper and Lead, from* 1-16*th, to* 2 *inches thick.*

Thick.	Cast iron.		Mall. iron.		Copper.		Lead.	
	Libs.	*oz.*	*Libs.*	*oz.*	*Libs.*	*oz.*	*Libs.*	*oz.*
1 sixteenth	2	6.6	2	7.8	2	15	3	11
2 —	4	13.3	4	15.6	5	14	7	6
3 —	7	4.	7	7.4	8	13	11	1
4 —	9	10.6	9	15.2	11	12	14	12
5 —	12	1.3	12	7.1	14	11	18	7
6 —	14	8.	14	14.9	17	10	22	2
7 —	16	14.7	17	6.7	20	9	25	13
8 —	19	5.3	19	14.5	23	8	29	8
9 —	21	12.	22	6.3	26	7	33	3
10 —	24	2.7	24	14.2	29	6	36	14
11 —	26	9.3	27	6.	32	5	40	9
12 —	29	—	29	13.8	35	4	44	4
13 —	31	6.7	32	5.6	38	3	47	15
14 —	33	13.4	34	13.4	41	2	51	10
15 —	36	4.	37	5.3	44	1	55	5
1 inch	38	10.7	39	13.1	47	—	59	—
1 1/8 —	43	8.	44	12.7	52	14	66	1
1 1/4 —	48	5.3	49	12.3	58	12	73	12
1 3/8 —	53	2.7	54	12.	64	10	81	2
1 1/2 —	58	—	59	11.6	70	8	88	8
1 5/8 —	62	13.4	64	11.3	76	6	95	14
1 3/4 —	67	10.7	69	10.9	82	4	103	4
2 —	77	5.4	79	10.2	94	—	118	—

TABLE *of the Weight of a Lineal Foot of Malleable and Cast Iron Bars, from 6-16ths to 3 inches square.*

Sixteenths on the side.	Area in square sixteenths.	MALL. IRON. *Ounces weight.*	CAST IRON. *Ounces weight.*	ROUND RODS. The 16ths on the side is the diameter of rod. *Ounces weight.*
6	36	7.4736	. . .	5.83
7	49	10.1724	. . .	7.99
8	64	13.2864	12.8960	10.43
9	81	16.8156	.	13.20
10	100	20.7600	. . .	16.30
11	121	25.1196	. . .	19.72
12	144	29.8944	29.0160	23.47
13	169	35.0844	. . .	27.53
14	196	40.6896	. . .	31.94
15	225	46.7100	. . .	36.44
1 inch	256	53.1456	51.5840	41.50
1	289	59.9964	. . .	46.80
2	324	67.2624	. . .	52.47
3	361	74.9436	. . .	58.46
4	400	83.0400	80.6000	64.81
5	441	91.5516	. . .	71.41
6	484	100.4784	. . .	78.37
7	529	109.8204	. . .	85.66
8	576	119.5774	116.0640	93.27
9	625	129.7500	. . .	101.21
10	676	140.3376	. . .	109.46
11	729	151.3404	. . .	118.05
12	784	162.7584	157.9760	126.95
13	841	174.5916	. . .	136.19
14	900	186.8400	. . .	145.74
15	961	199.5036	. . .	155.62
2 inches	1024	212.5824	206.3360	165.82
1	1089	226.0764	. . .	176.34
2	1156	239.9856	. . .	187.19
3	1225	254.3100	. . .	198.36
4	1296	269.0496	261.1440	209.86
5	1369	284.2044	. . .	221.68
6	1444	299.7744	. . .	233.83
7	1521	315.7596	. . .	246.30
8	1600	332.1600	322.4000	259.09
9	1681	348.9756	. . .	272.20
10	1764	366.2064	. . .	285.64
11	1849	383.8524	. . .	299.41
12	1936	401.9136	390.1040	313.49
13	2025	420.8900	. . .	327.91
14	2116	439.2816	. . .	342.64
15	2209	458.5884	. . .	357.70
3 inches	3304	478.3104	464.2560	373.09

Example to show the application of the foregoing Table to find the weight of Flat Iron.

What is the weight of a flat bar of malleable iron 3 inches broad, $\frac{3}{8}$ thick, and 50 feet long?

$3 \times 16 = 48 \times 3 = 144$ square 16ths, section of bar: look in the column of areas in the Table, and opposite 144 is 29.8944 oz. weight of one foot of the bar, multiply 29.8944 by 50 feet = 1494.72 oz. or 93.42 lbs.

Find the sixteenths in the section of the bar, and look for the number in the column of areas; if the number be not exact, take the nearest to it.

The foregoing Tables have been calculated from Hutton's Specific Gravities; those of cast and malleable iron and lead agree very nearly with those given by other authors; but the specific gravity of copper, though heavier than that given by Hatchett, which is 8.800; still, from copper being frequently alloyed with lead, it is supposed that Hutton's, which is 9000, will be nearest the weight of copper commonly used.

As a Table of Specific Gravities is often found useful, I have inserted the following; but for calculating the weights of metals, I would recommend Dr. Hutton's Table. See page 49.

TABLE OF SPECIFIC GRAVITIES.

METALS.

	Specific Gravity.	Weight of a cubic inch in ounces avoir.
Arsenic,	5763	3.335
Cast antimony,	6702	3.878
Cast zinc,	7190	4.161
Cast iron,	7207	4.165
Cast tin,	7291	4.219
Bar iron,	7788	4.507
Cast nickel,	7807	4.513
Cast cobalt,	7811	4.520
Hard steel,	7816	4.523
Soft steel,	7833	4.533

	Specific Gravity.	Weight of a cubic inch in ounces avoir
Cast brass,	8395	4.858
Cast copper,	8788	5.085
Cast bismuth,	9822	5.684
Cast silver,	10474	6.061
Hammered silver,	10510	6.082
Cast lead,	11352	6.569
Mercury,	13568	7.872
Jeweller's gold,	15709	9.091
Gold coin,	17647	10.212
Cast gold, pure,	19258	11.145
Pure gold, hammered,	19361	11.212
Platinum, pure,	19500	11.285
Platinum, hammered,	20336	11.777
Platinum wire,	21041	12.176

Note. All metals become specifically heavier by hammering.

STONES, EARTHS, &c.

	Specific Gravity.	Weight of a cub. foot in lbs. avoir.
Brick,	2000	125.00
Sulphur,	2033	127.08
Stone, paving,	2416	151.00
Stone, common,	2520	157.50
Granite, red,	2654	165.84
Glass. green,	2642	
Glass, white,	2892	
Glass, bottle,	2733	
Pebble,	2664	166.50
Slate,	2672	167.00
Marble,	2742	171.38
Chalk,	2784	174.00
Basalt,	2864	179.00
Hone, white razor,	2876	179.75
Limestone,	3179	198.68

RESINS, &c.

Wax,	897	
Tallow,	945	
Bone of an ox,	1659	
Ivory,	1822	

LIQUIDS.

	Specific Gravity.	Weight of a cub. foot in lbs. avoir.
Air at the earth's surface,	$1\frac{2}{7}$	
Oil of turpentine,	870	
Olive oil,	915	
Distilled water,	1000	
Sea water,	1028	
Nitric acid,	1218	
Vitriol,	1841	

WOODS.

Cork,	246	15.00
Poplar,	383	23.94
Larch,	544	34.00
Elm and new English pine,	556	34.75
Mahogany, Honduras,	560	35.00
Willow,	585	36.56
Cedar,	596	37.25
Pitch pine,	560	41.25
Pear tree,	661	41.31
Wainut,	671	41.94
Pine, forest,	694	43.37
Elder,	695	43.44
Beech,	696	43.50
Cherry tree,	715	44.68
Teak,	745	46.56
Maple and Riga pine,	750	46.87
Ash and Dantzic oak,	760	47.50
Yew, Dutch,	788	49.25
Apple tree,	793	49.56
Alder,	800	50.00
Yew, Spanish,	807	50.44
Mahogany, Spanish,	852	53.25
Oak, American,	872	54.50
Boxwood, French,	912	57.00
Logwood,	913	57.06
Oak, English,	970	51.87
Do. sixty years cut,	1170	73.12
Ebony,	1331	83.18
Lignumvitæ,	1333	83.31

Application of the foregoing Table.

A block of marble, measuring 6 feet long and 4 feet square, lies at a wharf, and the wharfinger wishes to know if his 10 ton crane is sufficiently strong to lift it.

$6 \times 4 \times 4 = 96$, cubic feet in the block.
171.38 lbs. weight of a cubic foot. (*See Table.*)

$$\frac{171.38 \times 96}{\text{lbs. in 1 ton} = 2240} = 7 \text{ ton } 7 \text{ cwt. weight of block.}$$

The 10 ton crane is therefore sufficiently strong to lift it.

There are several slabs of limestone which measure altogether 300 cubic feet, and it is proposed to bring them down a river on a raft formed of teak logs, and which can most conveniently form a raft 42 feet long and 18 feet broad, what depth shall it require to be to float the slabs?

198.7 lbs. weight of a cubic foot of limestone. (*See Table.*)

$$\frac{1000}{16} = 62.5 \text{ lbs. weight of a cubic feet of water.}$$

$$\frac{198.7 \times 300}{18 \times 42 \times 62.5} = 15 \text{ inches depth the slabs will sink the raft.}$$

1000 : 12 : : 745 : 9, that is a cubic foot of teak sinks 9 inches in water, of course 3 inches of wood above water; therefore $\frac{15}{3} = 5$ feet depth the raft will sink with the slabs, which, added to 9 inches, gives the depth the raft will sink in the water, and therefore the raft should not be made less than 6 feet deep.

12 : 6 : : 9 : 4.5 = depth the raft will sink.
1.25 = depth the slabs will sink the raft.
6.75 = depth the raft will sink in the water when carrying the slabs.

TABLE *of the Properties of Various Bodies.*

BODIES.	Specific Gravity.	Weight of a cubic foot.	Will bear on a square inch without permanent alteration.	Melts at degrees.	Cohesive force of a square inch.	Crushed by a force on square inch.	Absorbs of its weight of water.	Strength compared with Cast Iron.
WOODS.		*Libs.*	*Libs.*					
Ash	0.75	47.5	3540	- - -	- - -	- - -	- -	.23
Beech	0.696	45.3	2360	- - -	- - -	- - -	- - -	.15
Elm	0.544	34.	3240	- - -	- - -	- - -	- - -	.21
Yellow and Red Pine	0.557	34.8	4290	- - -	- - -	- - -	- - -	.3
White do.	0.47	29.3	3630	- - -	- - -	- - -	- - -	.23
Mahogany	0.56	35.	3800	- - -	- - -	- - -	- - -	.24
English Oak	0.83	52.	3960	- - -	- - -	- - -	- - -	.25
American Yellow Pine	0.46	26.75	3900	- - -	- - -	- - -	- - -	.25
Larch	0.560	35.	2065	- - -	- - -	- - -	- - -	.136
METALS.								
Cast Brass	8.37	506.25	6700	1869	18000	- - -	- - -	.435
Cast Iron	7.207	450.	15300	3479	- - -	93000	- - -	1.
Copper	8.75	549.	- - -	2548	33000			
Malleable Iron	7.6	475.	17800	- - -	- - -	- - -	- - -	1.12
Hammered do.	- - -	487.						
Cast Lead	11.352	709.5	1500	612	- - -	- - -	- - -	.096
Steel	7.84	490.	- - -	- - -	130000			
Cast Tin	7.291	455.7	2880	442	- - -	- - -	- - -	.182
Cast Zinc	7.028	439.25	5700	648	- - -	- - -	- - -	.365
Cast Gun Metal	8.153	509.13	10000	- - -	- - -	- -	- - -	.65
STONE, &c.								
Brick	1.841	115.	- - -	- - -	275	562	.066	
Chalk	3.215	144.7	- - -	- - -	- - -	500		
Clay	2.	125.						
Aberdeen Granite	2.625	164.	- - -	- - -	- - -	10910		
White Marble	2.706	169.	- - -	- - -	1811	6000		
Red Porphyry	2.871	179.	- - -	- - -	- - -	35568		
Welsh Slate	2.752	172.	- - -	- - -	11500			
Portland Stone	2.113	132.	- - -	- - -	857	3729	.0625	
Bath do.	1.975	123.4	- - -	- - -	478	- - -	.07	
Craiglelth do.	2.362	147.6	- - -	- - -	772	5490	.6158	
Dundee do.	2.621	163.8	- - -	- - -	2661	6630	.002	

By the last column of this Table, the rules for the strength of cast iron can be applied to the various bodies.

TABLE *of the Weight of Cast Iron Pipes.*

Bore.	Thick.	Long.	Weight.			Bore.	Thick.	Long.	Weight.			Bore.	Thick.	Long.	Weight.		
1	¼	3 ft 6	0	0	12	6½	⅜	9	3	2	21	11½	¾	9	7	2	8
	⅜	3 ft 6	0	0	21		¾	9	4	1	21		1	9	10	1	2
1½	¼	4 ft 6	0	0	21		1	9	6	0	14	12	1/16	9	5	0	24
	⅜	4 ft 6	0	1	4	7	3/16	9	2	1	7		5/16	9	6	2	8
2	¼	6	0	1	8		¼	9	3	0	7		¾	9	7	3	20
	5/16	6	0	2	0		5/16	9	3	3	20		1	9	10	3	0
2½	¼	6	0	1	16		¼	9	4	3	5	12½	½	9	5	1	16
	⅜	6	0	2	10		1	9	6	2	4		5/16	9	6	3	9
	½	6	0	3	10	7½	3/16	9	2	2	4		¾	9	8	1	0
3	¼	9	0	2	20		½	9	3	1	6		1	9	11	0	21
	5/16	9	1	0	6		5/16	9	4	0	22	13	½	9	5	2	20
	½	9	1	1	12		¼	9	5	0	10		5/16	9	7	0	14
	⅝	9	1	3	6		1	9	7	0	0		¾	9	8	2	7
	¾	9	2	1	0	8	½	9	3	2	4		1	9	11	2	12
3½	¼	9	0	3	0		5/16	9	4	1	25	13½	½	9	5	3	7
	5/16	9	1	0	21		¾	9	5	1	18		5/16	9	7	1	12
	½	9	1	2	14		1	9	7	1	16		¾	9	8	3	16
	⅝	9	2	0	8	8½	1/16	9	3	3	2		1	9	11	3	24
	¾	9	2	2	0		3/16	9	4	2	26	14	½	9	6	0	4
4	¼	9	1	1	10		¼	9	5	2	22		5/16	9	7	2	16
	½	9	1	3	12		1	9	7	3	8		¾	9	9	1	0
	⅝	9	2	1	12	9	1/16	9	4	0	0		1	9	12	1	14
	¾	9	2	3	21		5/16	9	5	0	4	14½	½	9	6	0	24
4½	⅜	9	1	2	2		¾	9	6	0	2		5/16	9	7	3	14
	½	9	2	0	4		1	9	8	0	26		¾	9	9	2	2
	5/16	9	2	2	14	9½	1/16	9	4	0	18		1	9	12	3	6
	¾	9	3	0	21		5/16	9	5	1	0	15	½	9	6	1	21
5	⅜	9	1	2	22		¾	9	6	1	6		5/16	9	8	0	14
	½	9	2	1	10		1	9	8	2	20		¾	9	9	3	7
	5/16	9	2	3	17	10	½	9	4	1	10		1	9	13	0	26
	¾	9	3	1	24		5/16	9	5	1	26		1¼	9	16	3	5
5½	3/16	9	1	3	10		¾	9	6	2	14	15½	½	9	6	2	14
	½	9	2	2	0		1	9	9	0	8		5/16	9	8	1	14
	5/16	9	3	0	18	10½	½	9	4	2	14		¾	9	10	0	10
	¾	9	3	3	7		5/16	9	5	3	7		1	9	13	2	17
	1	9	5	0	12		¾	9	7	0	0		1¼	9	17	1	6
6	⅜	9	2	0	0		1	9	9	2	0	16	½	9	7	0	22
	½	9	2	2	21	11	½	9	4	3	14		5/16	9	8	3	7
	5/16	9	3	1	17		5/16	9	6	0	11		¾	9	10	1	20
	¾	9	4	0	16		¾	9	7	1	7		1	9	14	0	8
	1	9	5	2	20		1	9	9	3	20		1¼	9	17	3	14
6½	⅜	9	2	0	16	11½	½	9	5	0	7		1½	9	21	3	4
	½	9	2	3	20		5/16	9	6	1	12		2	9	29	3	21

The foregoing Table of the weight of cast iron pipes, gives the length of pipe according to the diameter of bore as generally used in practice.

Diameter of bore in inches.
Thickness of metal in inches.
Length of pipe in feet.

It is found to be of great use in making out estimates of pipes :—for instance, it is required to know the weight of a range of pipes 225 feet long, $7\frac{1}{2}$ inches diameter of bore, and metal $\frac{5}{8}$ of an inch thick.

9)225

25 pipes in the whole length.

One pipe weighs 4 . 0 . 22, which multiplied by 25, is equal to 104 . 3 . 18, or 5 tons, 4 cwt. 3 quarters, 18 libs, weight of the whole range.

The following is a Table of the velocity of motion, for boring cast iron cylinders, pumps, &c. and heavy turning, with fixed cutters.

It will be observed, that the surface bored is constantly the same, 78.54 feet per minute ; this velocity is found to be the most advantageous : a velocity greater than this, not only takes the temper out of the cutters, but also causing more heat, expands the metal ; and if the machine stops but for a few seconds, a mark is left from the contraction of the metal.

Turning has a velocity double to that of boring.

TABLE.

BORING.		TURNING.	
Inches diameter.	Revolutions of bar per minute.	Inches diameter.	Revolution of shaft per minute.
1	25.	1	50.
2	12.5	2	25.
3	8.33	3	16.67
4	6.25	4	12.50
5	5.	5	10.
6	4.16	6	8.32
7	3.57	7	7.15
8	3.125	8	6.25
9	2.77	9	5.55
10	2.5	10	5.
15	1.66	15	3.33
20	1.25	20	2.50
25	1.	25	2.
30	0.833	30	1.667
35	0.714	35	1.430
40	0.625	40	1.250
45	0.56	45	1.12
50	0.5	50	1.
60	0.417	60	0.834
70	0.358	70	0.716
80	0.313	80	0.626
90	0.278	90	0.556
100	0.25	100	0.50

N. B. The progression of the cutters may be 1-16th of an inch for the first cut, and for the last 1-24th.

If hand tools are employed in turning, the velocity may be considerably increased.

BUILDING.

LAYING FLOORS.

Flooring boards are mostly made of pine. The first class are selected free from knots, shakes, sap-wood, or cross-grained stuff; the second class consists of boards also free from shakes and sap-wood, but not from small sound knots; the third class contains the residue of any parcel, or such boards as cannot be included in either of the preceding classes. When an agreement is entered into for the erection of a building, the quality of the boards should be specified, to prevent subsequent disputes. As all boards shrink in the course of time, and as the quantity of their contraction increases with their dimensions, floors which are laid with very broad boards, soon exhibit, at the joints, wide fissures that have an unpleasant appearance. It is therefore the practice in good houses, not only to select the best part of the wood, but to cut the boards into narrow scantlings; so that, if properly seasoned, and laid close at first, their shrinking afterwards is so small as to make no openings of consequence. Boards about five inches broad may be reckoned narrow, but when they measure nine inches or more in the same direction, they must be considered broad.

The manner of jointing floor boards, and fastening them down upon the joists, is performed in a variety of ways, the most usual of which is, to plane the edges of the board quite square, that is, at right angles to the upper and under surface, and then, placing them as closely to each other as possible, to nail them down from the upper surface. Sometimes, particularly when the wood is known to be insufficiently seasoned after the first board has been fastened down, the fourth board is secured in like manner, the two intermediate boards are then made somewhat wider than the space to receive them, and forced into their places by jumping upon them. To do this with the most ease and advantage, the intermediate boards are laid aslant, so as to be highest in the middle, and those edges which are placed together being sloped a little, so as to form rather less than a right angle with their respective upper serfaces, they are,

by an adequate weight, at once compressed and levelled. The fourth board of the last series becomes the first of the next, and the operation, which is called folding the boards, is repeated till the floor is finished. The nails are driven in a little below the surface of these boards, and the cavity is filled with glazier's putty. But in rooms not intended to be carpeted, and yet where a neat and clean appearance is indispensable, the use of putty must be avoided, and the nails must not be driven in from the top. This object is obtained by doweling the joints, that is, driving wooden pins into them in the middle of their thickness, and parallel to the surface, in the same manner as the coopers joint the boards forming the ends of their casks. In this case, one-half of each pin entering the edges placed together, the boards, if the dowels be sufficiently numerous and properly placed, cannot rise or sink but in conjunction. The best place for the dowels is in the middle of the space between the joints. In the best doweled work, the nails are concealed when the floor is finished, for they are driven in slantwise through the outer edge only of each board. Sometimes the joints of flooring boards are rabbeted, that they may lap over each other a little way, and sometimes toothed into each other, or, as it is technically expressed, ploughed and tongued. When either of these methods is adopted, the boards are not separated on their contraction so as to leave an aperture between each pair, through which any thing can drop ; but such floors are more costly than others, not only on account of the extra labour, but the greater quantity of wood which they require.

It is always desirable to cover a floor with boards in one length ; but as this may not always be convenient, when it is not done, the ends of the two boards that meet are called headings. The headings should invariably be upon a joist, and two of them should never be together in the same line.

Before the boards are laid, it is necessary to examine whether the upper sides of the joists all lie in the same plane. The defect they are most liable to, is that of being depressed in the middle ; in which case they must be raised by the addition of suitable pieces, but if found too protuberant, they must be reduced by the adze.

Yellow pine, well seasoned, is one of the best woods that can be selected for floors, and retains its colour for a long time; whereas the white sort, by frequent washing, becomes blackish and disagreeable in its appearance.

Proportion of Timbers, &c.

In the treatise entitled the "British Carpenter," already referred to, are given the following Tables to show the proportions of timbers for small and large buildings:

PROPORTIONS OF TIMBERS FOR SMALL BUILDINGS

Bearing Posts of Pine	
Height	Scantling
if 8 feet	4 inches square
10	5
12	6

Bearing Posts of Oak	
Height	Scantling
if 10 feet	6 inches square
12	8
14	10

Girders of Pine	
Bearing	Scantling
if 16 feet	8 inches by 11
20	10 12½
24	12 14

Girders of Oak	
Bearing	Scantling
if 16 feet	10 inches by 13
20	12 14
24	14 15

Joists of Pine	
Bearing	Scantling
if 6 feet	5 inches by 2½
9	6½ 2½
12	8 2½

Joists of Oak	
Bearing	Scantling
if 6 feet	5 inches by 3
9	7½ 3
12	10 3

Bridgings of Pine	
Bearing	Scantling
if 6 feet	4 inches by 2½
8	5 2¾
10	6 3

Bridgings of Oak	
Bearing	Scantling
if 6 feet	4 inches by 3
8	5½ 3
10	7 3

Small Rafters of Pine	
Bearing	Scantling
if 8 feet	3½ inches by 2½
10	4½ 2
12	5½ 2½

Small Rafters of Oak	
Bearing	Scantling
if 8 feet	4½ inches by 3
10	5½ 3
12	6½ 3

Beams of Pine, or Ties	
Length	Scantling
if 30 feet	6 inches by 7
45	9 8½
60	12 11

Beams of Oak, or Ties	
Length	Scantling
if 30 feet	7 inches by 8
45	10 11½
60	13 15

Principal Rafters of Pine			*Principal Rafters of Oak*		
	Scantling			Scantling	
Length	Top	Bottom	Length	Top	Bottom
if 24 feet	5 by 7	6 by 7	if 24 feet	7 by 8	8 by 9
36	6½ 8	8 10	36	8 9	9 10½
48	8 10	10 12	48	9 10	10 12

PROPORTION OF TIMBERS FOR LARGE BUILDINGS.

Bearing Posts of Pine		*Bearing Posts of Oak*	
Height	Scantling	Height	Scantling
if 8 feet	5 inches square	if 8 feet	8 inches square
12	8	12	12
16	10	16	16

Girders of Pine		*Girders of Oak*	
Bearing	Scantling	Bearing	Scantling
if 16 feet	9½ inches by 13	if 16 feet	12 inches by 14
20	12 14	20	15 15
24	13½ 15	24	18 16

Joists of Pine		*Joists of Oak*	
Bearing	Scantling	Bearing	Scantling
if 6 feet	5 inches by 3	if 6 feet	6 inches by 3
9	7½ 3	9	9 3
12	10 3	12	12 3

Bridgings of Pine		*Bridgings of Oak*	
Bearing	Scantling	Bearing	Scantling
if 6 feet	4 inches by 3	if 6 feet	5 inches by 3½
8	5½ 3	8	6½ 3½
10	7 3	10	8 3½

Small Rafters of Pine		*Small Rafters of Oak*	
Bearing	Scantling	Bearing	Scantling
if 8 feet	4½ inches by 3	if 8 feet	5½ inches by 3
10	5½ 3	10	7 3
12	6½ 3	12	9 3

Beams of Pine, or Ties		*Beams of Oak, or Ties*	
Length	Scantling	Length	Scantling
if 30 feet	7 inches by 8	if 30 feet	8 inches by 9
45	10 11½	45	11 12½
60	13 15	60	14 16

Principal Rafters of Pine			*Principal Rafters of Oak*		
	Scantling			Scantling	
Length	Top	Bottom	Length	Top	Bottom
if 24 feet	7 by 9	8 by 9	if 24 feet	8 by 9	9 by 12
36	8 9	9 10½	36	9 10	10 10
48	9 10	10 12	48	10 13	12 14

The author of the preceding Tables observes, that though they seem so plain as not to need explanation, yet a few remarks might be subjoined with propriety. All binding or strong joists, he then adds, ought to be half as thick again as common joists; that is, if a common joist be given three inches thick, a binding joist should be four inches and a half thick, although of the same depth.

If it be not convenient to allow the posts in partitions to be square, which is the best form, in such cases, multiply the square of the side of the posts, as here given, by itself: for instance, if it be six inches square, then as six times six is thirty-six, to keep this post nearly to the same strength, find two numbers producing the same amount; as suppose the partition to be four inches thick, then let the post be nine inches the other way, so that nine times four being thirty-six, the area of its horizontal section is the same, and its strength nearly equal to the square post.

Posts that go to the height of two or three stories, need not hold the proportions given in the table, because at every floor they meet with a tie. Admit a post to be thirty feet high, and that in this height there are three stories, two of ten feet and one of eight feet; look for posts of pine ten feet high, their scantling is five inches square, that is, twenty-five square inches, which double for the two stories; and also take that of eight feet high, being four inches, that is, sixteen inches square, all which being added together, make sixty-six inches; so that such a post would be rather more than eight inches square. On occasion it may be lessened in each story as it rises.

All beams, ties, and principal rafters, ought to be cut or forced in framing to a chamber, or roundness, on the upper side, and the convexity may be about one inch in eighteen or twenty feet. The reason is, that all timber, partly from its own weight, but principally from the weight of the covering or other burden it has to bear, will swag; and unless prepared in this manner, that it may never become concave, a degree of unsightliness, and often of inconvenience, will be produced.

The joists in floors, the purlines (or timbers into which the small rafters are tenoned in roofs,) &c., should not exceed twelve feet in the length of their bearing, or from sup-

port to support. The strong joists of floors should not be at a greater distance than five feet, nor common joists more than ten or twelve inches apart.

According to the experiments of Muschenbroek, pine is able to bear compression in the direction of the length of its fibres, or to sustain as a post, a much greater weight than oak, but is far inferior to oak when the weight is suspended. In the preceding tables, therefore, the scantlings of pine bearing posts and principal rafters are properly made *less* than those of oak; but for other timbers, particularly for ties, many are of opinion that the proportions of the author's tables should be reversed, and the scantling which he has assigned to pine should be given to oak.

BRICKLAYERS' WORK.

The top line is the dimensions in feet in length. The left hand column is the number of bricks the wall is thick. The content is given in rods of $16\frac{1}{2}$ feet square and decimal parts of a rod, all at 10 feet high. This explanation extends to the first and second Tables. But the third Table, the first column is length in feet and the content in roods of 7 yards or 63 superficial feet, without any regard to thickness. The third column is number of feet long. And fourth column the content, and so on with every two columns to the end.

No. of bricks broad.	1	2	3	4	5	6	7	8	9	10	11	12	15	20
1	.0124	.0246	.0370	.0492	.0615	.0743	.0863	.0985	.111	.123	.135	.148	.185	.245
2	.0247	.0492	.0738	.0983	.123	.148	.173	.197	.222	.246	.270	.296	.370	.491
3	.0370	.0738	.111	.148	.184	.222	.260	.296	.333	.370	.405	.443	.552	.740
4	.0492	.0984	.148	.196	.246	.296	.345	.350	.444	.442	.540	.590	.790	.985
5	.0615	.123	.184	.246	.307	.370	.432	.492	.555	.615	.675	.740	.920	.123

Second Table *at Ten Feet High.*

No. of bricks broad.	Feet. 30	Feet. 40	Feet. 50	Feet. 60	Feet. 70	Feet. 80	Feet. 90	Feet. 100	Feet. 200	Feet. 300	Feet. 400	Feet. 500	Feet. 600	Feet. 700
1	.369	.430	.615	.740	.862	.885	1.11	1.23	2.46	3.70	4.90	6.15	7.40	8.62
2	.740	.183	1.23	1.48	1.73	1.97	2.21	2.46	4.90	7.40	9.85	12.3	14.8	17.3
3	1.11	1.48	1.84	2.22	2.58	2.95	3.33	3.70	7.38	11.0	14.8	18.4	22.2	25.8
4	1.48	1.97	2.46	2.95	3.45	3.94	4.44	4.92	9.84	14.8	19.7	24.6	29.5	34 5
5	1.84	2.46	3.07	3.70	4.31	4.92	5.53	6.15	12.3	18.5	24.6	30.7	37.0	43.1

Third Table *at Ten Feet High.*

Content given in roods of 7 yards long and 1 wide, or 63 superficial feet.

Feet long.	Content in Roods.	Feet long.	Content in Roods.	Feet long.	Content in Roods	Feet long.	Content in Roods.	Feet long.	Content in Roods.	Feet long.	Content in Roods.	Feet long.	Content in Roods.	Feet long.	Content in Roods.
1	.156	8	1.27	35	5.57	70	11.2	110	17.5	180	28.4	700	122		
2	.318	9	1.44	40	6.37	75	12	120	19.2	190	30.1	800	128		
3	.478	10	1.60	45	7.20	80	12.8	130	20.7	200	31.8	900	144		
4	.638	15	2.35	50	8.00	85	13.6	140	22.2	300	47.8	1000	160		
5	.800	20	3.18	55	8.80	90	14.4	150	23.8	400	63.7	1100	175		
6	.960	25	4.	60	9.57	95	15.2	160	25.4	500	80.0	1200	191		
7	1.12	30	4.88	65	10.4	100	16	170	26.8	600	96.0	1300	207		

CIRCLES AND DIAMETERS.

THE diameter of a circle being given, to find the circumference; or the circumference being given, to find the diameter.

RULE.

Multiply the diameter by 3.1416, and the product will be the circumference; or,

Divide the circumference by 3.1416, and the quotient will be the diameter

NOTE 1.—As 7 is to 22, so is the diameter to the circumference; or, as 22 is to 7, so is the circumference to the diameter.

EXAMPLES.

(1.) If the diameter of a circle be 17, what is the circumference?

Here $3.1417 \times 17 = 53.4072 =$ *circumference.*

(2.) If the circumference of a circle be 354, what is the diameter?

Here $\frac{354.000}{3.1416} = 112.681 =$ *diameter.*

(3.) What is the circumference of a circle whose diameter is 40 feet? Ans. 125.6640.

(4.) What is the circumference of a circle whose diameter is 12 feet? Ans. 37.6992.

(5.) If the circumference of the earth be 25,000 miles, what is the diameter? Ans. 7958 nearly.

(6.) The base of a cone is a circle; what is its diameter when the circumference is 54 feet? Ans. 20.3718.

The following Table contains diameters and circumferences in inches and parts, from half an inch to 65 inches.

Diameter in Inches and Half.	Circumference in Inches and Parts.	Diameter in Inches and Half.	Circumference in Inches and Parts.	Diameter in Inches and Half.	Circumference in Inches and Parts.	Diameter in Inches and Half.	Circumference in Inches and Parts.	Diameter in Inches and Half.	Circumference in Inches and Parts.
½	1.57	13½	42.4	26½	83.25	39½	124.1	52½	164.93
1	3.14	14	43.98	27	84.82	40	125.66	53	166.5
1½	4.71	14½	45.55	27½	86.39	40½	127.23	53½	168
2	6.28	15	47.12	28	87.96	41	128.8	54	169.64
2½	7.85	15½	48.70	28½	89.53	41½	130.37	54½	171.21
3	9.42	16	50.26	29	91.1	42	131.94	55	172.78
3½	10.99	16½	51.83	29½	92.67	42½	133.51	55½	174.35
4	12.56	17	53.40	30	94.28	43	135.	56	175.92
4½	14.13	17½	54.97	30½	95.81	43½	136.65	56½	177.5
5	15.7	18	56.54	31	97.39	44	138.23	57	179
5½	17.28	18½	58.11	31½	98.96	44½	139.8	57½	180.64
6	18.85	19	59.69	32	100.53	45	141.37	58	182.21
6½	20.42	19½	61.26	32½	102.1	45½	142.94	58½	183.78
7	21.99	20	62.8	33	103.67	46	144.52	59	185.35
7½	23.56	20½	64.4	33½	105.24	46½	146	59½	186.92
8	25.13	21	65.97	34	106.81	47	147.65	60	188.49
8½	26.7	21½	67.54	34½	108.38	47½	149.22	60½	190
9	28.27	22	69.11	35	109.95	48	150.79	61	191.63
9½	29.84	22½	70.7	35½	111.52	48½	152.36	61½	193.2
10	31.4	23	72.25	36	113	49	153.93	62	194.77
10½	32.98	23½	73.82	36½	114.66	49½	155.5	62½	196.35
11	34.55	24	75.4	37	116.23	50	157	63	197.92
11½	36.12	24½	76.9	37½	117.81	50½	158.65	63½	199.49
12	37.70	25	78.54	38	119.38	51	160.23	64	201
12½	39.27	25½	80.11	38½	120.9	51½	161.79	64½	202.63
13	40.84	26	81.68	39	122.52	52	163.36	65	204.2

EXAMPLE.

Required the circumference of a circle of 7 inches diameter. See the above Table; in column 1st, is 7 inches diameter, and against that, in column 2d, is 21.99, or what might be considered 22.

THE STEAM ENGINE RENDERED EASY

WITH PLATES.

Having already described the Steam Engine in all its operations, the design here is, to commence with it in its simplest state, and to proceed to a full description of the high and low pressure system; for the more immediate advantage of new beginners, and those who have not had an opportunity of studying this subject.

FIG. I.

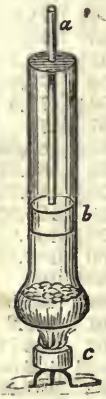


Fig. I. represents a glass tube of about $\frac{3}{4}$ of an inch wide and seven or eight inches long; *a* is a wooden rod about ten inches long, called a piston rod, with a piece of leather wrapped round it at *b*, the piston. After the water in the glass tube has been made to boil by the lamp *c* long enough to expel the atmospheric air, introduce the piston a little way into the tube, and plunge the tube into water, and you will find that the piston will instantly be driven downwards. Hold the tube over the lamp again, and the piston will be driven upwards, and so on as often as you please, to heat and cool it. The reasons are these: by plunging the tube into cold water the steam is suddenly condensed, and a vacuum is created, into which the piston is forced by the pressure of the atmosphere. When the water in the bulb resumes the process of boiling, by being replaced over the lamp, steam is generated below the piston, which expands itself in the tube and forces the piston upwards.

This is "a *steam engine*" in its simplest form, and you will readily conceive that if the piston rod is attached to a lever or wheel, it can communicate force and motion.

In the engine represented in figure I, the piston is forced *upwards only* by the expansive power of the steam; when the steam is condensed and a vacuum is created below the piston, it is forced downwards by the pressure of the atmo

sphere. This is what is therefore called "an *atmospheric* engine." After each stroke of the piston the cylinder has to be cooled, in order that the necessary condensation of the steam may take place, which occasions a great waste of fuel. There is another inconvenience attending this engine, viz. the rate of the motion cannot be well regulated.

FIG. II.

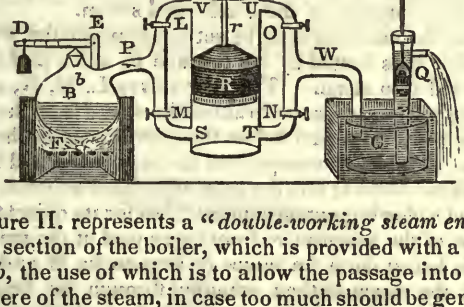


Figure II. represents a "*double-working steam engine.*" *B* is a section of the boiler, which is provided with a safety-valve *b*, the use of which is to allow the passage into the atmosphere of the steam, in case too much should be generated for the safety of the machine. This safety-valve is regulated by the lever D E, and the moveable weight D. V U S T indicate the cylinder, *r* the piston rod, and R the piston, which is filled in, or "stuffed" as it is called, with wool, tow, felt or metal, in such a way as to be as nearly air and steam tight as possible, without creating too much friction against the sides of the cylinder, as the piston moves up and down. K is a box stuffed in like manner, and for the like purpose, through which the piston rod passes. The steam pipe P communicates with the boiler, and through it the steam is conveyed from the boiler to the cylinder. This pipe, it will be observed, is divided into two branches, L and M. This is for the purpose of conveying the steam, either *above* or *below* the piston, according as it is required to force the piston down or up. Each branch is provided with a valve or a stop-cock, by which the communication between the boiler and cylinder can be cut off and opened again. On the opposite side of the cylinder are two similar

branches, O and N, forming, where they unite, the "eduction pipe" W, which is connected with the "*condenser*" C. The branches O N being each provided with a valve or stop-cock, which are alternately opened and closed, and used for the purpose of discharging the steam which has performed its office into the condenser. The condenser is kept constantly cool by surrounding it by a well of cold water. By this means, the discharged steam, which passes through the eduction pipe, is instantaneously condensed. The pump Q serves for the important purpose of continually freeing the condenser of air and water, and preparing it for the reception of the discharged steam.

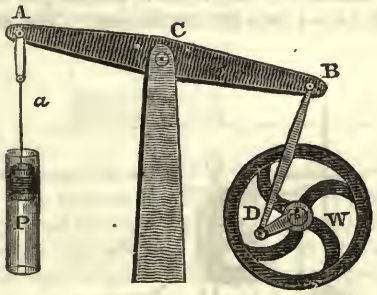
When the machine is to be set in operation, the water in the boiler B is heated by the furnace F, and a part of it is converted into steam. The four valves L, M, N, and O, are then all opened, so as to admit the steam from the boiler to pass both above and below the piston, and at the same time to admit of its escape into the condenser, and thence through the pump Q into the open air. This process, which is called "blowing out the engine," has for its object the expulsion of the atmosphere from every part of the machine.

This being done the valves or stop-cocks M and O are closed, the steam is then admitted through the branch L only, passing the valve or stop-cock L, and entering into the cylinder above the piston, which it forces down to the bottom of the cylinder, and thus imparts the first motion to the engine. As the piston thus descends, the steam which was below it in the cylinder is forced through the branch N and eduction pipe W into the condenser, and being turned into water, is drawn off by the pump Q. The valves or stop-cocks L and N are now closed, and M and O are at the same time opened, upon which the steam rushes from the boiler through the steam pipe P and branch M under the piston, and forces it to the top of the cylinder, and the steam which was above the piston then passes through the branch O and eduction pipe W into the condenser in like manner, and so on, the opposite valves or stop-cocks opening and shutting, alternately, producing an alternate upward and downward motion in the piston rod, which being communicated to the machinery, keeps it in a continual and regular motion.

The valves or stop-cocks L, M, N, O, in the branches, are usually opened and shut, and the pump Q worked by the engine, being effected by levers connected with the piston rod, which makes the motion more uniform and regular.

In this, which is a low-pressure engine, the pressure of the steam is averaged at fifteen pounds at the square inch, which is equal to the weight of one atmosphere, and the power is proportioned to the surface of the piston and bore of the cylinder. It is generally calculated by the power of so many horses. The power of the engine may be increased or diminished by increasing or diminishing the size of the piston and cylinder, for in proportion to the pressure of the steam upon the piston, will it be moved up and down with greater or less force.

Fig. III.



If the motion required be *rotary*, the piston rod A, Fig. III., is connected to one end of a lever, whose fulcrum, C, is in the centre, and the other end of the lever, B, is connected with the wheel by means of a crank, D.

The safety-valve *b*, Fig. II., is shaped conically, and is kept in its place by the lever D E, charged with the weight D. This weight can be moved further from or nearer to the safety-valve, according as we wish the steam in the boiler to attain a greater or less degree of elasticity. Although it is generally stated that in the low-pressure engine the steam is used as it is generated, at 212°, which is equal

to just one atmosphere, yet it is necessary to attach a small additional weight to the lever D E, to increase the elasticity of the steam in the boiler, to a degree which enables it to blow out with force sufficient to prevent the admission of the atmosphere into the machine.

Instead of the valves and stop-cocks above described for the admission and escape of the steam, a *single slide* is substituted. It consists, as may be seen in fig. IV. and V., in a slide S, which can be moved up and down from L to M. This is effected by the levers M, N, O, and an eccentric, which is moved by the turning of the wheel. When the slide is in the position represented in fig. IV. the steam in the boiler is admitted through the steam pipe P, through the branch *q r*, and thence through the opening *u* in the lower part of the cylinder, to force upwards the piston, while the steam that was above the piston is discharged through the passage *a b d n o e* into the condenser. The next turn of

FIG. IV.

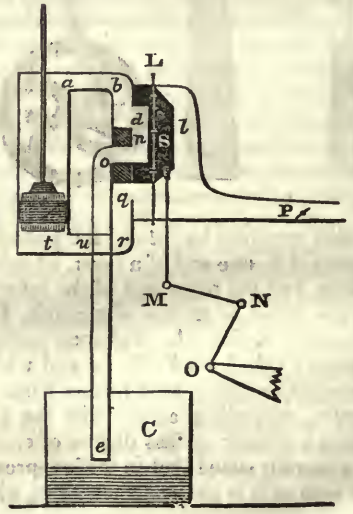
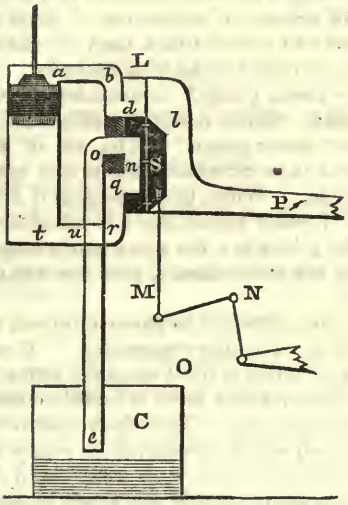


FIG. V



the wheel places the slide S in the position represented in fig. V. The communication being cut off, the steam can no longer pass through the branch *q r*; but it has free access through the branch *l d b a* into the upper part of the cylinder above the piston, forcing it down, while the steam which was below the piston finds a way opened for its escape through the branch *t u r q n o e* into the condenser.

In the "high pressure engine" the steam from both above and below the piston is discharged directly into the atmosphere; it therefore occupies less space, as it requires neither condenser, water-well nor air pump. But the atmosphere having access to that surface of the piston which is opposite to the steam, and exercising upon it a pressure equal to 15 pounds to the square inch, it follows, that the steam employed for this engine must be confined until it attains an elasticity that is sufficient, first, to overcome that atmospheric pressure, and then to drive the machinery. But when the boiler and cylinder of the high-pressure en-

gine are strong, a powerful pressure can be exercised with a very small volume of steam, but of great elasticity.

There are two hollow tubes, each provided with a stop-cock, both communicating with the boiler. One of these, called the "steam gauge," communicates with the steam; and the other, which communicates with the water, is called the "water-gauge." The use of the steam and water gauges is to ascertain if the proper quantity of water is in the boiler. When the stop-cock of the steam guage is opened, if water issues, there is too much of that liquid in the boiler; if, when the water gauge stop-cock is opened, nothing but steam issues, then the water is too low in the boiler.

There is also attached to some engines, a little instrument which is called the "governor." It consists of two balls, each of which is fixed upon the lower end of a lever, the upper end of which lever is loosely connected with an upright shaft by a pin. The shaft is connected with the fly wheel, from which it receives its rotary motion. The balls, according to the law of centrifugal forces, recede from or approach towards the shaft, in the ratio of the velocity of the governor-shaft and fly wheel. The governor is also connected, by appropriate machinery, with a valve in the steam pipe, which valve it opens or shuts; so that if the machine goes faster than it ought to do, the valve of the steam pipe gently closes, and shutting off a portion of the steam from the cylinder, retards the motion; on the other hand, if the machine goes too slow, the shaft of the governor revolves with less velocity, the balls being less acted upon by the centrifugal force, descend and approach the shaft, and by means of the machinery aforesaid, the valve of the steam pipe gently opens and more steam is allowed to pass from the boiler to the cylinder. Thus does the engine regulate its own velocity, making it more uniform.

THE

MANAGERS AND OVERSEERS' ASSISTANT;

CONTAINING THE

ART OF CALCULATION IN A COTTON MILL,

Through all its various operations, from the Raw Material into Yarn and Cloth. Arranged in a concise and simple manner. By an Operative Spinner.

INTRODUCTORY.

It is presumed, that this small treatise will be rendered valuable, not only to *Overseers* and *Managers*, but to every one who may feel desirous to attain a situation as manager or overseer in a cotton mill. The different branches are illustrated with simplicity and perspicuity, and may be easily understood by those persons who have but little time to devote to study. An individual who fully comprehends the following rules, may discharge the various duties attached to an official situation in a cotton-mill, with ease and credit to himself--and to the entire satisfaction of his employers.

MANAGER'S ASSISTANT.

To find the counts of Cotton, at the end of every operation from the raw material into Yarn.

Suppose a lap 8 feet long weighs one pound two ounces, allowing the two ounces to waste in going through all its operations.

RULE.

840 yards being in one hank, weigh one pound, consequently, there must be one hank in the pound, that being multiplied by 3 brings it into feet, and divided by 8 feet, will be the 315th part of a hank

EXAMPLE.

840 yards in one hank.
3 feet in one yard.

8)2520

315 Answer required.

To find the counts after going through a caraing engine.

Suppose a draught of a carding engine to be $78\frac{3}{4}$, and a lap before going through be the 315th part of a hank.

RULE.

Reduce the $78\frac{3}{4}$ into fourth, and divide that product by 315, and it will be one-fourth of a hank.

EXAMPLE.

$78\frac{3}{4}$
4

315)315(1 that is $\frac{1}{4}$ of a hank.
315

To find the draught of a carding engine.

Suppose the diamater of the doffer cylinder be 18 inches with a wheel upon the doffer shaft of 30 teeth, and work into another upon the side shaft of 35 teeth, on the other end of the side shaft is a 20 that works into a wheel upon the feed rollers of a 150 teeth, and the diameter of the feed roller is 2 inches. The draught is required.

RULE.

Multiply the 30 on the doffer end, by the 20 on the side shaft that works in the wheel upon the feed roller, then by the 2 inches the diameter of the feed roller for a divisor. Then multiply the 150 upon the feed roller by 18 inches the diameter of the doffer; then by the 35 on the side shaft for a dividend, and the draught will be $78\frac{3}{4}$.

EXAMPLE.

	30	150
	20	18
	600	1200
	2	150
Divisor,	12 00	2700
		35
		13500
		8100
		945 00(78¾ Answer required.
		84
		105
		96
		9

To find in what proportion a carding engine should cara to furnish the mules with a proper quantity of preparation in changing from one count to another.

Suppose a pair of mules be spinning 80's weft, with 85 turns in a certain length of lap going up at the carding engine, weighing 9 lbs., and the mule changing to 90's twist, with 105 turns: the lap of the same length is required.

RULE.

Ninety's twist requiring a lighter lap than 80's weft, and 105 turns require a lighter lap than 85 turns: multiply the 105 by 90's for a divisor, and the 85 turns by 80's, then by 9 pounds, the weight of the lap for a dividend. The answer will be nearly 6 lb. 7½ oz.

EXAMPLE.

80 90 105 — 105 90 — 9450 Divisor.

85 105 — 85 80 — 6800 — 9

61200(6 lb. 7 oz. Answer.
56700

4500
16 oz. in 1 pound.

27000
4500

72000(7 oz.
66150

8850

To find the counts after going through a drawing frame.

Suppose the carding to be of ¼ of a hank, and goes through 3 boxes of drawings, and puts up 6 ends at each box, and the draught of the first box to be 5¾, and the second to be 6, and the third box to be six and six twenty-thirds.

RULE:

Multiply the doubling at each box one into another for a divisor, and the draught of each box one into another for a dividend, and the answer will be one-fourth of a hank, after going through the three heads of drawing, consequently, nothing here is gained but doubling.

The draught of the first box and the doubling, must be brought into fourths, the draught of the last box and the doubling brought into twenty-thirds.

EXAMPLE.

1st box 6 ends	24	23 1st box $5\frac{3}{4}$	
	6	6 ends, " 6	
2d, " 6 "	144	138	
	138	144 3d box $6\frac{6}{23}$	
3d, " 6 "	1152	552	
	432	552	
	144	138	
Divisor,	19872	)19872(1 or $\frac{1}{4}$ of a hank.	
		19872	

To find the draught of the last box to gain nothing but doubling.

Suppose 3 heads of drawing have 6 ends put up at each head, and the draught of the first be $5\frac{3}{4}$, and the draught of the second 6: the draught of the last box is required.

RULE.

Multiply the draught of the first and second box for a divisor; then multiply the doubling of three boxes one into another for a dividend, and the draught of the last box will be $\frac{6}{23}$.

Note. The draught of the first box must be brought into fourths, consequently, the dividend must be brought into fourths also.

EXAMPLE.

	$5\frac{3}{4}$	6
	4	6
	23	36
	6	6
Divisor,	138	216
		4
		864
		828 ($6\frac{6}{23}$. Answer.
		36

To find the draught of a drawing frame with 4 rollers.

When a drawing frame has 4 rollers, there will be 3 draughts. The first draught $1\frac{1}{2}$, the second roller 2 of a draught. The draught of the front roller is required, allowing the whole of the draughts to be 9.

RULE.

Multiply the first draught by $1\frac{1}{2}$ by the second 2, and divide the whole of the draughts that is 9 by that product, and the draught of the first roller will be 3.

EXAMPLE.

	1 5	3)9	
	2		
		3	Answer required.
Divisor,	3		

To find the counts when the last box drawing has gone through a slubbing frame.

Suppose the last box drawing be $\frac{1}{4}$ of a hank, and go up single at a slubbing frame, with a 20 pinion wheel on the coupling shaft, a 60 top carrier, a 40 back roller wheel, and a 30 change wheel: the counts are required.

RULE.

Multiply the 20 pinion wheel by the 30 change wheel for a divisor; then multiply the 60 top carrier by the 40 back roller wheel for the dividend, and the draught will be 4, consequently will be one hank in the pound.

EXAMPLE.

	30	60
	20	40
Divisor,	6|00	24|00
		24 (4 draughts, or 1 hank in

the pound. Answer required.

To find the change wheel when the last box drawing has gone through a slubbing frame.

Suppose the last box drawing be $\frac{1}{4}$ of a hank, and go up single at the slubbing frame with a 20 pinion wheel on the front roller, and the top carrier 60, and the back roller wheel 40, and the draught to be 4: the change wheel is required.

RULE.

Multiply the 20 upon the front roller, by the draught 4 for a divisor, and the top carrier 60, by the back roller wheel 40, for the dividend, the change wheel required will be 30.

EXAMPLE.

	20	60
	4	40
Divisor,	80	2400
		24 (30 Answer.
		0

To find the counts after going through a roving billy.

Suppose a bobbin of one hank be drawn into a roving and put up two ends, with a 20 pinion wheel and an 80 top carrier, and a 60 back roller wheel, and a 30 change wheel: the number of hanks of the roving is required.

RULE.

Multiply the 20 pinion wheel by the 2 ends put up at the back. Then by the 30 change wheel for a divisor. Then multiply the 80 top carrier by the 60 back roller wheel for a dividend, and the roving required will be 4 hanks.

EXAMPLE.

	20	80
	2	60
	40	4800
	30	4800 (4 hanks the answer.
Divisor,	1200	

To draw a bobbin into a roving.

Suppose a bobbin of one hank be drawn into 4, and go up double at the billy, with a 20 pinion and an 80 top carrier, and a 60 back roller wheel. The change wheel is required.

RULE.

Multiply the pinion wheel by the 2 ends put up, and then by the 4 hanks roving for a divisor. Then multiply the 80 top carrier by the 60 back roller wheel for the dividend, and the change wheel required will be 30.

EXAMPLE.

	20	80
	2	60
	40	480|0
	4	48 '30 Answer.
Divisor,	160	0

To find the draught of a frame with two heads having the draught of the first head given to answer the purpose of both a slubbing frame, and a roving billy.

Suppose the last box drawing be of $\frac{1}{4}$ of a hank, and go up double at a frame with two heads, and be drawn into a four hank roving, and the draught of the first head be 5. The draught of the second head is required.

RULE.

The last box drawing being $\frac{1}{4}$ of a hank, and going up double, $\frac{1}{8}$ of a hank, that multiplied by 4 hanks wanted, and divided by the draught of the first head, that is 5; then the draught of the second head which is required, will be $6\frac{2}{5}$.

EXAMPLE.

8
4

5)32

$6\frac{2}{5}$ Answer.

To find the number of stretches upon a set of rovings.

Suppose the front roller of a roving billy makes 18 revolutions in one stretch, with a worm upon the coupling shaft that drives a wheel of 30 teeth, and a worm upon the same shaft with the 30 wheel, that drives a bell wheel with 120 teeth. The number of stretches is required, allowing the bell wheel to go once round.

RULE.

Multiply the 120 by the 30 for a dividend, and divide by the 18, that is, the revolutions of the front roller, and the number of stretches upon the roving will be 200.

EXAMPLE.

120
30

18)3600(200 stretches the answer.

To find the counts after going through a mule.

Suppose a roving of 4 hanks be drawn into yarn with a 20 pinion wheel, an 80 top carrier, a 60 back roller wheel, a 30 change wheel, and the length of the stretch put up 60 inches, and the length of the yarn turned out from the rollers 53 inches. The number of hanks is required.

RULE.

Multiply the pinion 20 by the change wheel 30, and the product by 53 inches, that the rollers turn out for a divisor; multiply the 80 top carrier by the 60 back roller wheel, and by the 60 inches put up; then by the 4 hanks roving for the dividend, and the answer will be $36\frac{1}{5}\frac{2}{3}$.

EXAMPLE.

20	80
30	60
600	4800
53	60
1800	288000
3000	4
Divisor, 31800	)1152000 (36$\frac{1}{5}\frac{2}{3}$ Answer.
	95400
	198000
	190800
	7200

To find the turns.

Suppose a thread of yarn requires 30 revolutions of the spindles per inch, and put up 60 inches of a stretch, and the spindles make 20 revolutions for one turn of the rim: the number of turns is required.

RULE. Multiply the 60 inches put up by the 30 revolutions required per inch, and divide by 20 the number of revolutions of the spindle for one turn of the rim, and the number of turns required will be 90.

EXAMPLE.

60
30

2|0)180|0

90 Answer.

To find a wheel to put on the bottom of the long driver, to make the rollers turn out a certain number of inches, in a certain number of turns.

Suppose the rollers turn out 53 inches in 55 turns, with a 53 wheel on the rim shaft, a 55 wheel on the top of the long driver, 102 upon the coupling shaft, and the circumference of the front roller be 3 inches: the wheel on the bottom of the long driver is required.

RULE.

Multiply the 53 wheel on the rim shaft by the 55 turns, and by the 3 inches, the circumference of the front roller for a divisor. Multiply the 55 on the top of the long driver by the 53 inches the rollers turn out, then by the 102 on the coupling shaft for the dividend, and the wheel required will be 34.

EXAMPLE.

	53	55
	55	53
	265	165
	265	275
	2915	2915
	3	102
Divisor	8745	5830
		2915
		297330(34 Answer.
		26235
		34980
		34980

To find a wheel to put upon the bottom of the short driver, to draw a carriage out a certain number of inches, in a certain number of turns.

Suppose a carriage to be brought 58 inches in 55 turns, with a 20 upon the rim shaft, a 70 upon the top of the short driver, a 100 scrall wheel, and the circumference of the scrall $18\frac{5}{11}$ inches: the wheel upon the bottom of the short driver is required.

RULE.

Bring $18\frac{5}{11}$ into 11ths, and multiply that by 55 turns, and by the 20 upon the rim shaft for a divisor; then multiply the 58 inches by the 70 wheel on the top of the short driver, then by the 100 scrall wheel, and reduce that into 11ths for the dividend, and the wheel on the bottom of the short driver will be 20.

EXAMPLE.

$18\frac{5}{11}$	58	
11	70	
203	4050	
55	100	
1015	406000	
1015	11	
11165	4466000	(20 Answer.
20	4466000	
Divisor, 223300		

To find the number of hanks of the roving from the number of hanks of the mule in spinning.

Suppose a pair of mules be spinning 44's weft and put up 60 inches, and the carriage gains from the rollers 9 inches, with a 20 on the coupling shaft or pinion wheel, and a 100 top carrier, a 30 change wheel, a 50 back roller wheel. The number of hanks of the roving is required.

RULE.

Multiply the 40 hanks by the 9 inches the carriage gains, and divide by the 60 inches put up, it will show that 6 hanks are altered by the gaining of the carriage, and 6 hanks subtracted from the 40 hanks, 34 will remain; then multiply the 34 by the pinion wheel 20, and by the change wheel 30 for a dividend, and multiply the top carrier 100 by the 50 back roller wheel for a divisor and the roving required will be 4 $\frac{2}{25}$.

EXAMPLE.

	40	40
	9	6 subtracted.
	60)360	34 remains.
	6	20
		680
		30
	100	20400 ($4\frac{2}{25}$ Answer.
	50	20000
Divisor,	5000	400

To change from one count to another without changing the roving.

Suppose a pair of mules be spinning 40 hanks in the pound with 36 change wheel, and has to change to 60 hanks in the pound: the change wheel is required.

RULE.

As 60's will require a less change wheel than 40's, consequently, the 40 and 36 must be multiplied together for a dividend, and divide by the 60, and the change wheel required will be 24.

EXAMPLE.

As 60 : 40 36
40

6|0)144|0
24

To change from one count to another, when the change wheel and roving is required to be altered.

Suppose a pair of mules to be spinning 40's with a 4 hank roving, and a 30 change wheel, and is altered to 60's, with a 7 hank roving: the change wheel is required.

RULE.

Multiply the 60 by the 4 hank roving for a divisor; then multiply the 40 by the 7 hanks roving, and that by the 30 change wheel for the dividend, and the change wheel required will be 35.

EXAMPLE.

40 — 4 — 30
60 — 7 —

60 40
4 7

Divisor, 24|0 280
30

840|0 (35 Answer.
72

120
120

To find the circumference of a scrall to draw a carriage out a certain number of inches, in a certain number of turns.

Suppose a carriage be brought out 58 inches in 55 turns, with a 20 wheel upon a rim shaft, a 70 upon the top of the

short driver, a 20 on the bottom, and a 100 the scrall wheel; the circumference of the scrall is required.

RULE.

Multiply the 55 by the 20 upon the rim shaft; then by the 20 at the bottom of the short driver for a divisor; multiply the 58 inches by the 70 on the top of the short driver, then by 100 on the scrall shaft for the dividend, and the circumference of the scrall will be $18\frac{5}{11}$.

EXAMPLE.

	55	58	
	20	70	
	1100	4060	
	20	100	
Divisor,	22|000	)406000	($18\frac{5}{11}$ Answer.
		22	
		186	
		176	
		10	

To find the circumference of a mandosa pully, to draw out a carriage a certain number of inches, in a certain number of turns.

Suppose a carriage be brought out 58 inches in 55 turns, and a wheel on the rim shaft of 53 teeth, and a wheel on the top of the long driver of 55 teeth, a 34 on the bottom of the long driver, that works into a wheel on the coupling shaft of 100 teeth, and a wheel of 30 teeth on the same shaft that works in one on the mandosa shaft of 250 teeth: the circumference of the mandosa pully is required.

RULE.

Multiply the 55 turns by the 53 on the rim shaft, by 34 on the bottom of the long driver, by 30 on the coupling shaft for a divisor; multiply 55 on the top of the long driver by 100 on the coupling shaft, by 260 the mandosa

wheel, the 58 inches for the dividend, and the circumference of the mandosa pully will be 27 inches, 89 of a decimal, or nearly 28 inches.

EXAMPLE.

55	55	
53	100	
165	5500	
275	260	
2915	330000	
34	11000	
11660	1430000	
8745	58	
99110	11440000	
30	7150000	
29733|00	)829400|00	(27—89
	59466	
	234740	
	208131	
	266090	or nearly 28 inches.
	237864	
	282260	
	267597	
	14663	

To draw a roving into yarn.

Suppose a thread of $36\frac{1}{5}\frac{2}{3}$ be drawn from a 4 back roving, with a twenty pinion wheel, and an 80 top carrier, a 60 back roller wheel, and the number of inches put up 60, and the number of inches turned out of the rollers, 53 the change wheel is required.

RULE.

Reduce the $36\frac{1}{5}\frac{2}{3}$ into 53rds, then multiply the product by the pinion wheel 20, and by the 63 inches the rollers turn out for a divisor; multiply the 80 top carrier by the 60 back roller wheel, and by the 60 inches put up, then by the 4 hank roving; reduce those products into 53rds for the dividend, and divide it as in whole numbers, and the change wheel required will be 30.

EXAMPLE.

$36\frac{1}{5}\frac{2}{3}$	80
110	60
181	
	4800
1920	60
20	
	288000
38400	4
53	
	1152000
113200	53
192000	
	3456000
2035200 Div.	5760000

)610560|00 (30 Answer.
61056

To find a wheel to put on the middle roller, for the middle roller to draw from the back roller 6 into 7.

Suppose the diameter of the back roller be $\frac{8}{8}$ and the diameter of the middle roller to be $\frac{7}{8}$ of an inch, and the wheel upon the back roller be 24: the wheel on the middle roller is required.

RULE.

Multiply the 24 on the back roller by the $\frac{7}{8}$ of the middle roller, and divide it by the $\frac{8}{8}$ of the back roller, and the wheel required to take it up as the back roller delivered it, will be 21; that multiplied by 6, and divided by 7, will show that the wheel required on the middle roller to draw 6 into 7, will be 18.

EXAMPLE.

24
7
—
8)168
—
21
6
—
7)126
—
18 Answer required.

To find the draught of a mule.

Suppose the pinion wheel upon the coupling shaft be 20, the top carrier 120, change wheel 38, back roller wheel 54, and the diameter of the back roller $\frac{7}{8}$ of an inch, and the front roller $\frac{8}{8}$: the draught is required.

RULE.

Multiply the change wheel 38 by the pinion wheel 20, then $\frac{7}{8}$ diameter of the back roller for the divisor; then multiply the top carrier 120 by the back roller wheel 54, then by the diameter of the front roller $\frac{8}{8}$ for the dividend, and the draught will be $9\frac{99}{133}$.

EXAMPLE.

	38	120	
	20	54	
	—	—	
	760	480	
	7	600	
	—	—	
Divisor,	5320	6480	
		8	
		—	
		51840	($9\frac{99}{133}$ Answer.
		47880	
		—	
		3960	

To find the number of revolutions of the spindles for every inch of yarn.

Suppose a thread of yarn to be spun with 90 turns, and 20 revolutions of the spindle for one turn of the rim, and puts up 60 inches: the number of revolutions per inch is required.

RULE.

Multiply the 90 turns by the 20 revolutions of the spindle, and divide by 60 inches put up, and the number of revolutions per inch will be 30.

EXAMPLE.

90
20

60|0)180|0

30 Answer.

To find the counts of yarn, without the assistance of a compendious table.

Suppose one lea or 120 yards weigh 25 grains: the counts are required.

RULE.

Seven thousand grains being one pound, and 7 leas one hank, and a lea being a seventh part of a hank, and weighing 25 grains, 1000 grains must be divided by 25 grains, and the counts required will be 40's; and if 2 leas be taken, 2000 must be divided by what it weighs, and so on up to 7 leas.

EXAMPLE.

25)1000 (40 Answer.
100

To find in what portion to put twist in yarn per inch, in changing from one count to another.

Suppose a pair of mules are spinning 40's twist, with $22\frac{1}{2}$ revolutions of the spindle per inch, and change to 90's twist: the number of revolutions of the spindle per inch is required.

RULE.

Add $2\frac{1}{2}$ revolutions of the spindle for every 10 hanks, and it shows the number of revolutions required.

Note. 90's being 50 hanks finer than 40's, multiply $2\frac{1}{2}$ by 5 and it will give $12\frac{1}{2}$, that added to the $22\frac{1}{2}$ will show, that 90's require 35 revolutions per inch.

40's weft requiring $16\frac{1}{2}$ revolutions per inch, and $12\frac{1}{2}$ added to that, shows that 90's weft require 29 revolutions.

EXAMPLE.

Twist,	22.5	2|5
	12.5	5
	35.0	12|5
Weft,	16.5	25
	12.5	5
	29.0	12.5

To find the number of stretches upon a cop:

Suppose a cop run 10 leas with 80 turns of the reel in one lea, and 54 inches in one turn, and the number of inches the mule puts up is 60: the number of stretches is required.

RULE.

Multiply that 10 leas by the 80 turns of the reel in one lea, then by 54 inches in one turn, and divide by the 60 inches put up, and the number of stretches will be 720.

EXAMPLE.

10
80
800
54
6|0)4320|0
720 Answer.

To find the average counts of a set of Cops.

Suppose a mule have 420 spindles, and one cop run 10 leas, and the whole set weighs 15 pounds, the average counts are required.

RULE.

Multiply the 420 spindles by 10 leas for the dividend, then multiply the 15 pounds by 7 leas in one hank for a divisor, and the average counts will be 40's.

EXAMPLE.

	15	420
	7	10
Divisor	105	4200 (40 Ans.
		420

To find the Weight of a Warp.

Suppose a warp 270 yards long, with 33 beers, and 60 ends to each beer, and the number of hanks be 34's twist, the weight of the warp is required.

RULE.

Multiply the 270 by 33 beers, then by 60 ends in each beer, that will show the number of yards the warp contains; then divide the yards by 840, and it will show the number of hanks it contains; then divide the number of hanks by 34 hanks in the pound, and it will show the number of pounds; then multiply the remainder by 16, and divide by 34, as before, and the weight of the warp will be 18 pounds 11 ounces.

EXAMPLE.

	lbs. oz.
270	636(18 11
33	34
810	296
810	272
8910	24
60	16
84|0)53460|0(34	144
504	24
306	384(11
352	34
540	44
504	34
36	10

To find the Weight of Weft to fill a Warp.

Suppose a warp of 270 yards long be wove into cloth, and allowing 30 yards to mill up in the weaving and other waste, and the breadth of the cloth 29 inches, with 80 picks in each inch, and the number of hanks of the weft be 34 in the pound, the weight of the weft is required.

RULE.

Subtract 30 yards from the 270 yards, and 240 remain; that multiplied by 29 inches, the breadth of the cloth, then by 80 picks per inch, it will show the number of yards; then divide by 840, and it will bring it into hanks; then divide the hanks by 34 in the pound, and it will be 19 pounds; then multiply the remainder by 16, and divide by 34 as before: it will show the weight of weft required will be 19 lbs. 7 oz.

EXAMPLE.

```
        270
         30
        ---
        240
         29
        ----                  lbs. oz.
        2160          662(19    7
        480           34
        ----          --
        6960          322
          80          306
        -----         ---
84|0)55680|0(34         16
     304                16
     ---               ---
     528                96
     504               16
     ---               ---
     240               256(7
     168               238
     ---               ---
      72                18
```

To put a pair of mules in a good working condition, when the roller beam, spindle box, faller, and altogether is out of order.

Set the roller beam straight, then with a guage set the carriage strips all at one distance from the bottom centre of the front roller; when that is done, then with a level set all the carriage strips at the front of the bevel intended. Set all the ends of the spindle box bottoms at one distance to the carriage ends. String a line along the bottom of the spindle box, and set the line about a quarter of an inch from touching at each end: the best manner of doing this is by driving a small nail at each end of the spindle box, and lapping the line around them, and with the squaring bands square the carriage so that the line is

clear in the middle and the ends; and put in the bevel intended for the spindle at each end, and string a line along the top of the spindles also, and set them straight. Then set the faller and the stops at the back to the distance intended the spindles should be from the rollers.

A TABLE

Showing the requisite number of revolutions of the spindle for every inch of yarn, of twist and weft, beginning at 40*'s, and going up to* 200*'s.*

As no proper calculation can be made on account of the variations of the cotton, but, by observing the following Table, no person will be led into an error.

Twist.	Revolutions.	Weft.	Revolutions.
40	22½	40	16½
50	25	50	19
60	27½	60	21½
70	30	70	24
80	32½	80	26½
90	35	90	29
100	37½	100	31½
110	40	110	34
120	42½	120	36½
130	45	130	39
140	47½	140	41½
150	50	150	44
160	52½	160	46½
170	55	170	49
180	57½	180	51½
190	60	190	54
200	62½	200	56½

A TABLE

Of half a lea to try the hanks of bobbins, by penny-weights and grains, commencing at quarter of a hank and going up to five hanks.

Dwt.	Grains.	Hanks.	Dwt.	Grains.	Hanks.
83	8	$\frac{1}{4}$	7	13	$2\frac{3}{4}$
55	13	$\frac{3}{8}$	7	5	$2\frac{7}{8}$
41	16	$\frac{1}{2}$	6	22	3
33	8	$\frac{5}{8}$	6	16	$3\frac{1}{8}$
27	18	$\frac{3}{4}$	6	9	$3\frac{1}{4}$
23	19	$\frac{7}{8}$	6	4	$3\frac{3}{8}$
20	20	1	6	22	$3\frac{1}{2}$
18	12	$1\frac{1}{8}$	6	17	$3\frac{5}{8}$
16	16	$1\frac{1}{4}$	5	13	$3\frac{3}{4}$
15	3	$1\frac{3}{8}$	5	9	$3\frac{7}{8}$
13	21	$1\frac{1}{2}$	5	5	4
12	19	$1\frac{3}{8}$	5	0	$4\frac{1}{8}$
11	21	$1\frac{3}{4}$	4	21	$4\frac{1}{4}$
11	2	$1\frac{7}{3}$	4	18	$4\frac{3}{8}$
10	10	2	4	15	$4\frac{1}{2}$
9	19	$2\frac{1}{8}$	4	12	$4\frac{5}{8}$
9	6	$2\frac{3}{4}$	4	9	$4\frac{3}{4}$
8	18	$2\frac{3}{8}$	4	6	$4\frac{7}{8}$
8	6	$2\frac{1}{2}$	4	4	5
7	22	$2\frac{5}{8}$			

HYDROMETERS.

THE following Table shows the correspondence between Beaume, Twedale, and specific gravity; and no doubt will prove useful to dyers, colourers, calico printers, and bleachers.

TWEDALE'S HYDROMETER.

This instrument is in form and principle the same as Beaume's hydrometer for salts, except in the gradation. It takes cognizance only of liquids whose specific gravity exceeds that of water. Its zero is water at 60 degrees, and the space between and 1.850 (formerly regarded as the specific gravity of concentrated sulphuric acid,) is divided into 170 equal parts. It is in almost universal use among the practical chemists, calico printers, dyers, and bleachers, in England, Ireland, Scotland, and America. Its numbers are arranged on six glasses, which are called a whole set, (as the workmen term them.) No. 1 reaches to 24, No. 2 to 48, No. 3 to 74, No. 4 to 102, No. 5 to 138, No. 6 to 170.

BEAUME'S HYDROMETER.

There are two hydrometers which have been brought into use by Beaume, a chemical manufacturer of Paris, which are of easy construction, a point to which Beaume was particularly attentive in all his apparatus. Beaume's hydrometer for salts is sometimes used amongst the calico printers, bleachers, &c.; and I have often wondered why it was not more generally adopted, as it answers every purpose of Twedale's six glasses. The only objection that can be made against it is, that they cannot arrive at that point of accuracy which can be come at on Twedale's; but even this objection is groundless, providing a little care is exercised in ascertaining the strength of liquids. The following table will show the correspondence between Beaume, Twedale, and specific gravity, which may prove to be of practical utility.

Beaume.	Twedale.	Specific Gravity.	Beaume.	Twedale.	Specific Gravity.
0	0	1.000	38	72	1.359
1	1¼	1.007	39	74½	1.372
2	2½	1.014	40	77⅓	1.384
3	3¾	1.022	41	80¼	1.398
4	5¼	1.029	42	82¾	1.412
5	6¾	1.036	43	85½	1.426
6	8	1.044	44	88⅓	1.440
7	9¾	1.052	45	91	1.454
8	11¼	1.060	46	94⅛	1.470
9	12¾	1.067	47	97	1.485
10	14½	1.075	48	100	1.501
11	16¼	1.083	49	103⅓	1.526
12	18	1.091	50	106½	1.532
13	19½	1.100	51	109⅓	1.549
14	21¼	1.108	52	112½	1.566
15	23	1.116	53	115¾	1.583
16	24½	1.125	54	118½	1.601
17	26¼	1.134	55	123	1.618
18	28	1.143	56	127⅓	1.637
19	30	1.152	57	131¾	1.656
20	32	1.161	58	136⅓	1.676
21	34	1.171	59	139½	1.695
22	36	1.180	60	142½	1.714
23	38	1.190	61	147½	1.736
24	40	1.199	62	151⅔	1.758
25	42	1.210	63	155¾	1.779
26	44	1.221	64	160½	1.801
27	46	1.231	65	165⅛	1.823
28	48	1.242	66	170	1.847
29	50	1.252	67	—	1.872
30	52⅛	1.261	68	—	1.897
31	54¼	1.275	69	—	1.921
32	56½	1.286	70	—	1.946
33	59	1.298	71	—	1.974
34	61½	1.309	72	—	2.002
35	64⅛	1.321	73	—	2.031
36	66¾	1.334	74	—	2.059
37	68⅓	1.346	75	—	2.087

APPENDIX.

Form of a Common Negotiable Note.

$500 00

Philadelphia, May 12th, 1839.

Sixty days after date, I promise to pay to the order of John Slater, five hundred dollars, without defalcation, for value received. JOHN O'NEIL.

Note with Security.

$250 00

Philadelphia, June —, 1839

We, or either of us, promise to pay John Fox, or order, two hundred and fifty dollars, on the ninth day of June, one thousand eight hundred and thirty-nine, for value received, without defalcation. Witness our hands this —— day of March, one thousand eight hundred and thirty-nine.

JAMES PILKINGTON
JAMES ARKWRIGHT.

Bill of Exchange.

$1000 00

Philadelphia, March 27th, 1839.

Thirty days after sight, pay to John Brown, or order, this my first bill of exchange, for one thousand dollars, second and third of same tenor and date not being paid, without further advice from

Your humble servant,
JOHN GRIER.

To John Delany, Esq., New York.

Promissory Note.

$250 00

Philadelphia, March 2d, 1839.

Nine months after date, I promise to pay to Peter Pratt, or order, the sum of two hundred and fifty dollars, for value received, without defalcation. Witness my hand this second day of March, one thousand eight hundred and thirty-nine. GEORGE CAR.

No witness required.

Note with Interest

I promise to pay John Selby, or order, the sum of three hundred dollars, on demand, with interest till paid, for value received, without defalcation. Witness my hand, this first day of May, one thousand eight hundred and thirty-nine.

RICHARD BAXTER.

Form of an Inland Draft for Money, with Acceptance.

$750 00

Philadelphia, May 12th, 1839.

Six months after date, pay to the order of Henry Wild, seven hundred and fifty dollars, for value received, and place the same to my account. JAMES M. BROWN.

To Mr. ELY HALL,
Merchant,
Baltimore.

Accepted,
ABRAHAM COOK.

Bill of Lading.

Shipped, in good order, and well conditioned, by Jabez Hill, on board the called the whereof is master, now lying in the port of and bound for to say being marked and numbered, as in the margin, and are to be delivered in the like order and condition, at the port of the dangers of the seas only excepted, unto

or to assigns, paying freight for the said with primage and average accustomed.

In witness whereof, the master or mate of the said vessel hath affirmed to bills of lading, all of this tenor and date, one of which being accomplished, the others to stand void, dated in the day of 183

Bill of Parcels.

Philadelphia, January 30th, 1839.

Mr. John Hopkins,

Bought of James Pilkington,

2	doz.	Domestic shawls,	*a* $2.25 per doz.	$4.50
2½	"	Silk handkerchiefs	9.50 "	23.75
5	"	Double strap suspenders,	2.25 "	11.25
3	"	½ hose,	4.00 "	12.00
1 7/12	"	Fine Penknives,	3.00 "	4.75
2½	"	Best Razors,	8.75 "	21.87½
33	yds.	Domestic muslin,	*a* 12 per yd.	3.96
25	"	Satinet,	95 "	23.75
5	pieces	Calico, 165½ yds.,	12 "	19.86
				$125.69½

Receipt—General form.

Philadelphia, April 2d, 1839.

Received of Mr. Harlan Page, two hundred and seventy dollars, in full, for balance of account.

JOHN NEWTON.

$270 00

Letter of Credit.

Messrs. Carick & Rogers,—*Gentlemen*,

Allow me to introduce to your firm the bearer, James Pilkington, a gentleman about commencing business. Should he make a selection from your stock to the amount of five hundred dollars, I will be answerable for that sum in case of his non-payment. With esteem, yours,

SIMON PIKE.

FOREIGN COINS,

With their value in Federal money.

	D.	c.	m.
A johannes,	16	00	0
A doubloon,	14	93	0
A half johannes,	8	00	0
A moidore,	6	00	0
An old English guinea,	4	66	6
A French guinea,	4	60	0
An English sovereign,	4	44	4
Pound of Ireland,	4	10	2
A Spanish pistole,	3	77	7
A French pistole,	3	66	6
A pound flemish of Amsterdam,	2	42	7
Pagoda of India,	1	94	0
A sequin of Arabia,	1	66	6
An oz of Persia,	1	48	2
Tale of China,	1	48	0
Millree of Portugal,	1	27	3
English or French crown,	1	10	0
Dollar of Spain,	1	00	0
Rix dollar of Sweden,	1	02	5
Rix dollar of Denmark,	1	01	3
Scudo of Rome,		96	0
A ducat of Naples,		75	5
Ruble of Russia,		71	3
Rupee of Bengal,		55	5
A florin of Vienna,		46	6
Guilder of Holland,		39	0
Marc banco of Hamburg,		33	3
Piastre of Constantinople,		24	3
An English shilling,		22	2
A Pistareen,		20	0
Livre tournois of France,		17	6
A franc,		17	9
A lira of Florence,		15	0
Real of Spain,		9	7

STERLING MONEY,

With the par value in dollars, cents and mills.

Sterling. £	s.	d.		*United States.* $	cts.	m.
		1		1	8	
		2		3	7	
		3		5	5	
		4		7	4	
		5		9	2	
		6		11	1	
		7		12	9	
		8		14	8	
		9		16	6	
		10		18	5	
		11		20	3	
1	0			22	2	
1	6			33	3	
2	0			44	4	
2	6		*equal to*	55	5	
3	0			66	6	
3	6			77	7	
4	0			88	8	
4	6			1	00	0
5	0			1	11	1
5	6			1	22	2
6	0			1	33	3
6	6			1	44	4
7	0			1	55	5
7	6			1	66	6
8	0			1	77	7
8	6			1	88	8
9	0			2	00	0
9	6			2	11	1
10	0			2	22	2
20	0			4	44	4

Sterling. £ s. d.		*United States.* Dolls. cts. m.
10 0 0	*equal to*	44 44 4
20 0 0		88 88 8
30 0 0		133 33 3
40 0 0		177 77 7
50 0 0		222 22 2
100 0 0		444 44 4
500 0 0		2,222 22 2
1,000 0 0		4,444 44 4
5,000 0 0		22,222 22 2
10,000 0 0		44,444 44 4

DOLLARS AND CENTS,

With their par value in English money.

Dolls. cts.		£ s. d.
50		2 3
60		2 8
70		3 1
80		3 7
90		4 0
1 00		4 6
2 00		9 0
3 00		13 6
4 00		18 0
5 00	*equal to*	1 2 6
10 00		2 5 0
20 00		4 10 0
30 00		6 15 0
40 00		9 0 0
50 00		11 5 0
100 00		22 10 0
500 00		112 10 0
1,000 00		225 0 0
5,000 00		1,125 0 0
10,000 00		2,250 0 0
50,000 00		11,250 0 0

LOCOMOTIVE ENGINE.

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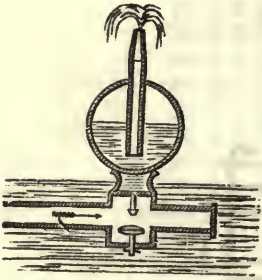

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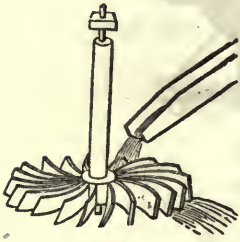

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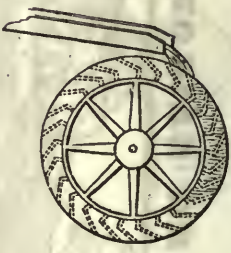

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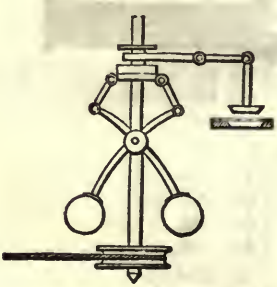

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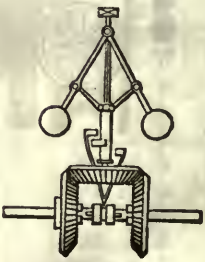

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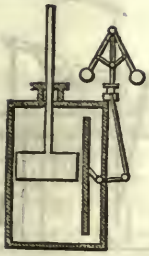

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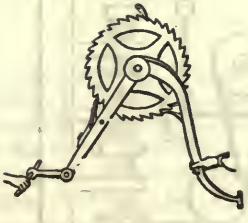

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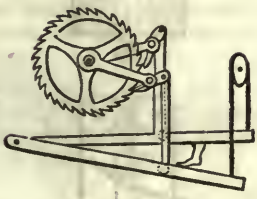

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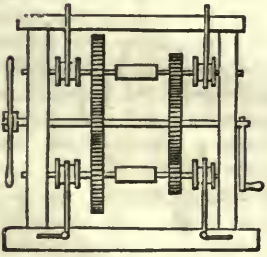

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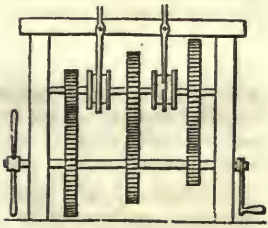

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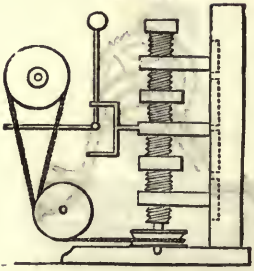

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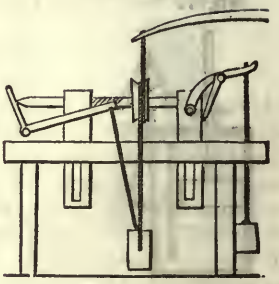

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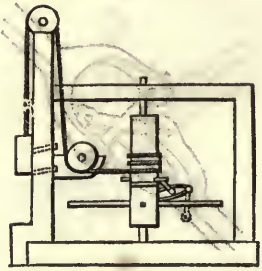

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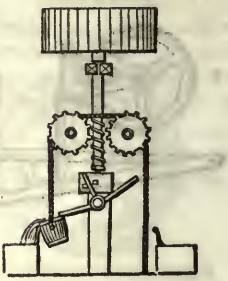

MECHANICAL MOVEMENTS.

No. 1,

Is the ingenious contrivance of the celebrated Montgolfier, generally called the hydraulic ram. In this apparatus, a current of water must flow through the tube, in the direction of the arrow, and escape at the lower valve which is kept open by a weight or spring, calculated according to the current; so that when the current arrives at its speed, this valve is closed, and the momentum which the water has acquired, forces open the upper valve which leads to an air chamber above, where the portion of the water which has passed the valve is received, and thence conducted in any required direction. As soon as the water which passes through the upper valve has come to a state of equilibrium, the stream at the arrow is necessarily at rest, and the lower valve is again opened by the spring or weight, at the same time that the valve leading to the air vessel is shut; thus by the alternate action of the two valves a portion of the stream is raised at every stroke, and carried to a reservoir above.

No. 2,

Represents a section of the oscillating column invented by M. Mannoury d' Ectot, for the purpose of elevating a portion of a given fall of water, above the level of the reservoir or head by means of a machine, all the parts of which are absolutely fixed. It consists of an upper or smaller tube which is constantly supplied with water, and the lower or larger tube constructed with a circular plate in the centre of the office, which receives the stream from the tube above. Upon allowing the water to descend it forms itself gradually into a cone on the circular plate, which cone protrudes into the smaller tube, so as to stop the flow of water downwards, and the regular supply continuing from above, the column in the upper tube rises until the cone on the circular plate gives way; this action is renewed periodically, and is regulated by the supply of water.

No. 3 *and* 4,

Are horizontal, and overshot water wheels.

No. 5,

Represents a revolving perpendicular shaft, carrying two balls which vibrate on levers, supported on a common centre above; these balls being acted on by the centrifugal force, fly out according to the velocity of the shaft. On the upper part of the shaft is placed a loose collar, connected to the opposite ends of the levers which carry the two balls, which by their position either elevate or depress the loose collar, and regulate the valve on the right, with which it is connected—this arrangement is generally used to regulate the supply of steam to engines.

No. 6,

Is an application of the governor for regulating the supply of water to wheels. The horizontal wheel is fixed to the revolving shaft, which receives motion from the water wheel, the speed of which is calculated to place the balls in the position here represented; but should it increase and thereby raise the sliding piece, a projection from the left of the shaft would strike against the part immediately above, and traverse the coupling on the horizontal shaft below, into gear with the left hand bevil, which being connected with the shaft, depresses the shuttle of the water wheel, and reduces the speed; but should the speed go too slow, and the balls collapse, the same projection would strike against the part immediately beneath it, and the bevil on the right would be connected with the shaft and turn it in an opposite direction, thereby raising the shuttle for a greater supply of water.

No. 7.

This is an useful governor for pumping engines, in which the work is suddenly varied. The solid piston here represented does not fit tight to the cylinder, which being filled with water is compelled to escape through the space, when

the passage on the right hand is shut, and thus work is thrown on the engine; but supposing the governor to resume its proper position, the valve in this side passage is opened, and the piston traverses without resistance.

No. 8 *and* 9.

Two arrangements for producing circular motion, by the hands or feet.

No. 10,

Is the universal joint generally attributed to Dr. Hook, by means of which the rotary motion of a shaft may be conveyed out of the straight line, without breaking its continuity.

No. 11

Is an arrangement of spur wheels running loose on their respective shafts, with which they can be connected by clutch boxes, so that the relative speed of the driver and the driven can be varied according to the proportion of the wheels which are connected to the shafts.

No. 12,

Is a combination of wheels running loose on their respective shafts, which will produce a variety of speeds in a similar manner to the one last mentioned.

No. 13.

Supposing the upper circle to represent a section of two drums close to each other, and running in opposite directions, the endless band which passes over the carrier pulley, below, will impart motion to the horizontal warve at the lower end of the perpendicular screw, which is supported by the upper and lower arms, but carries the central pieces as a moveable nut; to this nut is connected a fork, which at each extreme of its traverse vibrates the weighted lever, and thereby passes the endless band from one drum to the other, and reverses the revolution of the screw.

No. 14,

Is a machine proposed by M. Grandjean for cutting screws, in which the piece to be cut is traversed, by means of the bent lever on the left, which is acted on by the same treadle which gives the rotary motion.

No. 15,

Represents a machine for driving piles, in which the circular motion of the central perpendicular shaft is converted into alternate perpendicular motion, in the weight on the left. The principal contrivance by which the weight is relieved when at its highest elevation, is effected by the progressive increase of the coils of rope on the central shaft, which press on a small lever seen to the right hand, and disengages the upper part of the shaft, and allows the weight to run down; the upper part of the shaft being again re-connected as soon as the rope has run off.

No. 16.

Suppose the upper part of this figure to represent the sails of an horizontal mill, or any sufficient moving power to revolve the shaft which carries the spiral or worm below, and the shaft coupled immediately below the sails so as to allow a small vibration, thereby allowing the spiral or worm, to act on only one wheel at a time. At the back of these wheels and on the same shafts are placed pulleys, over which a rope is passed, carrying a bucket at each extremity, one of which is elevated at the same time that the other is lowered, by the alternative action of the worm on the opposite wheels. In the centre, and immediately below the worm is placed a vibrating piece, against which the bucket strikes in its ascent, and which, by means of an arm connected with the step in which the worm shaft is supported, traverses the worm from one wheel to the other, by which means the bucket which has delivered its water is again lowered, at the same time that the opposite one is elevated.

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